

# ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

WINTER 2014

www.aspirebridge.org

## **Jeremiah Morrow Bridge/I-71**

*Warren County, Ohio*

**SC 802 OVER THE BEAUFORT RIVER AND  
INTRACOASTAL WATERWAY**

*Port Royal and Lady's Island, South Carolina*

**I-85 YADKIN RIVER VETERANS MEMORIAL BRIDGES**

*Charlotte and Greensboro, North Carolina*

**PECOS STREET OVER I-70**

*Denver, Colorado*

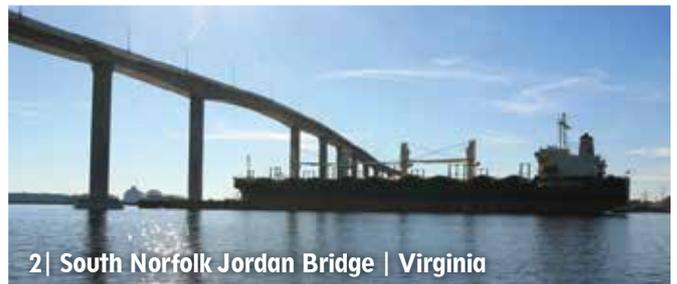
**ABC PROJECT - I-5 SKAGIT RIVER BRIDGE RAPID REPLACEMENT**

*Skagit County, Washington*



1 | AirTrain JFK, New York

# Sustainable Bridges for the Future

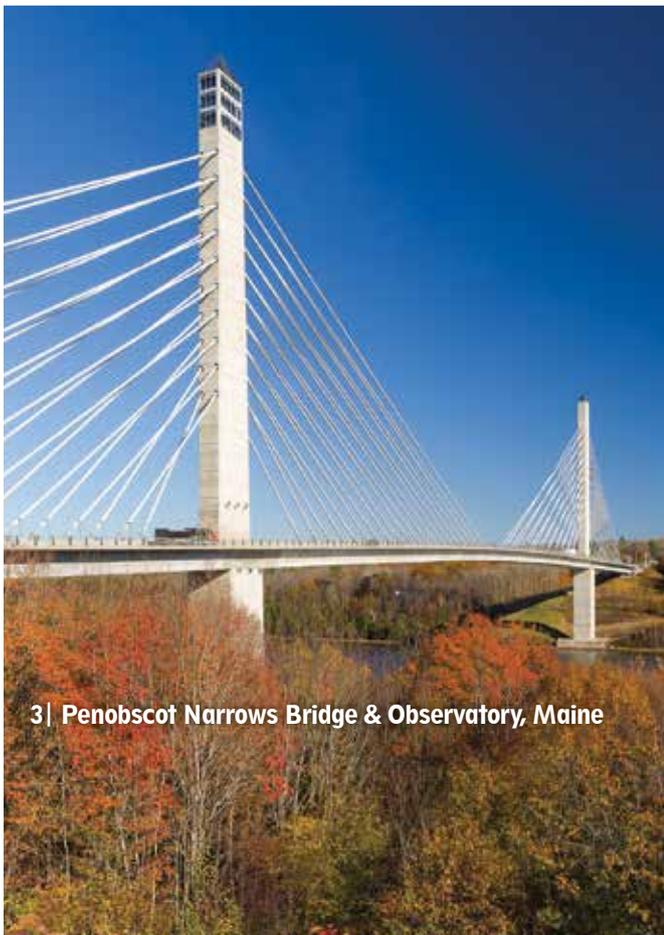


2 | South Norfolk Jordan Bridge | Virginia

FIGG customers' bridges each have special purpose – to relieve urban congestion, replace an aging structure, protect the environment, create a sense of place, enhance a local economy, and connect people in a meaningful way. The FIGG Team focuses on creative solutions to quickly deliver cost efficient, innovative and sustainable bridges that improve a region's quality of life.



**CREATING BRIDGES AS ART®**  
1.800.358.3444 | [www.figgbridge.com](http://www.figgbridge.com)



3 | Penobscot Narrows Bridge & Observatory, Maine

- 1 | AirTrain JFK, NY: 9 miles of elevated concrete segmental bridge for transit includes bridge down the median of the Van Wyck Expressway where over 160,000 vehicles per day travel.
- 2 | South Norfolk Jordan Bridge, VA: 5375' long concrete segmental bridge built in less than 2 years, with a 378' mainspan over the Elizabeth River, and a 142' vertical clearance.
- 3 | Penobscot Narrows Bridge and Observatory, MA: 1161' cable-stayed mainspan built using local labor and materials. The top of the pylon holds the tallest public observatory on a bridge in the world.



Photo: Jeff Weiler, OmniPro Services.



Photo: Collins Engineers Inc.



Photo: Wilson & Company.

## Features

**Beam, Longest and Neff** **6**  
*Beam, Longest and Neff expands from its Indiana base with new concrete techniques that create distinctive designs and lower costs.*

**Jeremiah Morrow Bridge / I-71** **12**  
*Ohio's tallest bridge spans the scenic Little Miami River.*

**SC 802 over the Beaufort River and Intracoastal Waterway Bridge** **16**  
*Barge collision necessitates new bridge, more-resilient design.*

**I-85 Yadkin River Veterans Memorial Bridges** **20**  
*New dual highway bridges improve safety, accessibility.*

**Pecos Street over I-70** **24**  
*Accelerated bridge construction techniques significantly reduce impacts to the traveling public.*

## Departments

<b>Editorial</b>	<b>2</b>
<b>Concrete Calendar</b>	<b>4</b>
<b>Reader Response</b>	<b>4</b>
<b>Perspective</b>	<b>10</b>
<b>Aesthetics Commentary</b>	<b>15</b>
<b>CCC—Downer Place Bridge</b>	<b>28</b>
<b>ABC—I-5 Skagit River Collapse and Rapid Replacement</b>	<b>29</b>
<b>FHWA—Another Bridge Life-Cycle Cost Analysis Tool for MAP-21</b>	<b>32</b>
<b>State—Maine</b>	<b>34</b>
<b>Concrete Bridge Preservation</b>	<b>36</b>
<b>Authority—New Jersey Turnpike Authority</b>	<b>38</b>
<b>Safety &amp; Serviceability</b>	<b>40</b>
<b>Concrete Connections</b>	<b>42</b>
<b>AASHTO LRFD—Sectional Design Model: Maximum or Concurrent Force Effects?</b>	<b>44</b>

Photo: Flatiron Construction Corp.

## Advertisers Index

Aegion . . . . .	11	FIGG . . . . .	Inside Front Cover	Larsa . . . . .	Inside Back Cover
CABA . . . . .	43	Headwaters . . . . .	18	MMFX . . . . .	15
Creative Design Resolutions . . . . .	3	Hilman Rollers . . . . .	30	PCI . . . . .	5, 19, 27
DSI/DYWIDAG Systems Intl-USA . . . . .	39	Holcim . . . . .	Back Cover	Stalite . . . . .	39



Photo: Ted Lacey Photography.

## Service Life Design for 100 Years?

Dr. Henry G. Russell, *Managing Technical Editor*

**T**his past summer, I had the opportunity to follow portions of Route 66 through Illinois. Back in 1926, Route 66 (known as the “Mother Road”) was the primary cross-country highway from Chicago, Ill., to Santa Monica, Calif. Although the route has been replaced by a modern interstate, portions of the old highway still exist.

Along this route, I encountered two concrete bridges: a reinforced concrete beam bridge built in 1921 and still carrying restricted traffic and a concrete arch bridge built in 1915. The concrete on both bridges is in remarkably good condition considering their ages.

This issue of *ASPIRE*<sup>TM</sup> includes articles about replacing or restoring three old bridges: the Downer Place Bridges from 1909, Jack’s Run Bridge from 1924, and Stillwater Viaduct from 1932. The last issue of *ASPIRE* featured the replacement of the West 7th Street Bridge in Fort Worth, Tex., originally built in 1913—100 years ago.

Did the designers and builders of these original bridges consider a service life?—I doubt it because they had this wonderful new material called concrete that would last forever!

Fast forward 100 years and we have a lot more options that can be used to produce durable and long-lasting concrete bridges. Are we smart enough to use current concrete technology to replicate what our predecessors accomplished without it?

The Strategic Highway Research Program 2 has been investigating service life beyond 100 years and their reports are being published. We should be able to design concrete bridges for at least a 100-year service life. In many aspects, we can learn from the durability

studies performed for major bridge crossings in Europe and Asia. Here, service-life design is approached in the same way as structural design. There are loads (environmental conditions) and there are resistances (freezing and thawing resistance, etc.). In the United States, we generally use a deemed-to-safety approach with a prescriptive specification.

According to the National Cooperative Highway Research Program Synthesis 441, state specifications for concrete to be used in bridges remain largely prescriptive. All state specifications now permit the use of one or more supplemental cementitious materials (SCMs) in concrete. The use of SCMs contributes to reducing chloride penetration to the reinforcement and is a step in the right direction. In addition, we can add corrosion inhibitors to raise the threshold level before reinforcement corrosion begins.

We also have alternative corrosion-resistant reinforcement that can be used including epoxy-coated reinforcement, metal-clad reinforcement, low-carbon chromium steel, stainless steel, and fiber-reinforced polymers.

AASHTO now has a standard practice, PP65-11, that provides a prescriptive approach and a performance approach for dealing with reactivity of concrete aggregates. This again is a step in the right direction.

Modern concrete technology provides us with many approaches to use as illustrated by the above examples. Our challenge is to select the appropriate ones to use for a given bridge in a particular location for the desired service life. Please let us know how you are approaching durability and extending service life on your projects. 



American Segmental Bridge Institute



Epoxy Interest Group



Expanded Shale Clay and Slate Institute



Portland Cement Association



Post-Tensioning Institute



Precast/Prestressed Concrete Institute

### Editor-in-Chief

William Nickas • wnickas@pci.org

### Managing Technical Editor

Dr. Henry G. Russell

### Program Manager

Nancy Turner • nturner@pci.org

### Associate Editors

Emily B. Lorenz

Craig A. Shutt

### Art Director

Paul Grigonis

### Layout Design

Tressa A. Park

Tom Scully

### Editorial Advisory Board

William Nickas, *Precast/Prestressed Concrete Institute*

William R. Cox, *American Segmental Bridge Institute*

Dr. David McDonald, *Epoxy Interest Group*

Dr. Henry G. Russell, *Henry G. Russell Inc.*

### Cover

Morning mist and sunlight captures the distinct architectural features of the Jeremiah Morrow Bridge, including curved deck overhangs, parabolic bottom soffit, and pier twin wall capitals. Photo: Ohio Department of Transportation

### Ad Sales

Jim Oestmann

Phone: (847) 838-0500 • Cell: (847) 924-5497

Fax: (847) 838-0555 • joestmann@arlpub.com

### Reprints

Paul Grigonis • pgrigonis@pci.org

### Publisher

Precast/Prestressed Concrete Institute

James G. Toscas, President

**Postmaster:** Send address changes to *ASPIRE*, 200 W. Adams St., Suite 2100, Chicago, IL 60606. Standard postage paid at Chicago, IL, and additional mailing offices.

*ASPIRE* (Vol. 8, No. 1), ISSN 1935-2093 is published quarterly by the Precast/Prestressed Concrete Institute.

Copyright 2014, Precast/Prestressed Concrete Institute.

If you have a project to be considered for *ASPIRE*, send information to *ASPIRE* 200 W. Adams St., Suite 2100 • Chicago, IL 60606  
phone: (312) 786-0300 • www.aspirebridge.org • e-mail: info@aspirebridge.org



**Creative Design Resolutions**  
is known as the industry leader for  
**Aesthetic Design and Master Planning Services**  
for bridge and highway projects across America

## CONTRIBUTING AUTHORS



**Nathaniel Coley** is an economist at the Federal Highway Administration (FHWA) and manages the Economic Analysis Program at FHWA Headquarters in Washington, D.C.



**Matthew M. Farrar** is the state bridge engineer with the Idaho Transportation Department in Boise. He serves on the AASHTO Subcommittee on Bridges and Structures, and is chairman of its Technical Committee T-18, Bridge Management, Evaluation, and Rehabilitation.



**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.



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



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



**Barton Newton** is the state bridge engineer with the California Department of Transportation in Sacramento. He serves on the AASHTO Subcommittee on Bridges and Structures, and is vice-chairman of its Technical Committee T-18, Bridge Management, Evaluation, and Rehabilitation.

## CONCRETE CALENDAR 2014

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

**January 12-16, 2014**  
**93rd Annual Meeting**  
**Transportation Research Board**  
Marriott Wardman Park, Omni Shoreman, and Hilton Washington Washington, D.C.

**January 20-24, 2014**  
**World of Concrete 2014**  
Las Vegas Convention Center Las Vegas, Nev.

**March 19-21, 2014**  
**DBIA Design-Build in Transportation**  
San José Convention Center San José, Calif.

**March 23-27, 2014**  
**ACI Spring Convention**  
Grand Sierra Resort Reno, Nev.

**April 14-15, 2014**  
**ASBI 2014 Grouting Certification Training**  
J. J. Pickle Research Campus The Commons Center Austin, Tex.

**April 24-27, 2014**  
**PCI Committee Days and Membership Conference**  
Hyatt Magnificent Mile Chicago, Ill.

**May 4-6, 2014**  
**PTI Annual Convention**  
Norfolk Waterside Marriott Norfolk, Va.

**June 8-12, 2014**  
**International Bridge Conference**  
David L. Lawrence Convention Center Pittsburgh, Pa.

**June 22-27, 2014**  
**2014 AASHTO Subcommittee on Bridges and Structures Meeting**  
Hyatt Regency Columbus, Ohio

**September 6-9, 2014**  
**PCI Annual Convention and Exhibition and National Bridge Conference**  
Gaylord National Resort and Convention Center National Harbor, Md.

**October 26-30, 2014**  
**ACI Fall Convention**  
Hilton, Washington Washington, D.C.

**October 27-28, 2014**  
**ASBI 26th Annual Convention**  
Hartford Marriott Downtown Hartford, Connecticut

## READER RESPONSE

*In the Fall 2013 issue of ASPIRE™, I read with interest the "West 7th Street Bridge" article and I wanted to offer the following additional information for your readers. The strand mentioned in the article—0.62-in.-diameter, 270 ksi, 7-wire prestressing steel strand—has been domestically supplied to the U.S. market for over ten years. Early on, most of the applications for this size of strand were post-tensioned stay-cable bridge projects. In these projects, the 0.62-in.-diameter, 270 ksi strand was the main tensile element in the stay cables. In 2010, 0.62-in.-diameter, 270 ksi strand was added to ASTM A416 for two reasons. The first was to make the specification of this size of strand easier for engineers. The second was to better reflect what is available in the current U.S. market. The 0.62-in.-diameter, 270 ksi strand that is currently produced and sold in the U.S. market has a nominal cross-sectional area of 0.231 in.<sup>2</sup> versus the traditional 0.6-in.-diameter, 270 ksi strand with a nominal cross-sectional area of 0.217 in.<sup>2</sup>*

Jon Cornelius  
EVP/General Manager, PC Strand Division  
Sumiden Wire Products Corporation  
Chair, North American Strand Producers Association  
Dickson, Tenn.

***Don't Miss Out on These Opportunities from PCI***



**THE 2014 PCI DESIGN AWARDS**  
Bridges and Transportation Structures



Photo courtesy of Hanson Structural Precast. Photographer: William Milner

The **52nd Annual PCI Design Awards** program submission site will open January 13, 2014. Visit [www.pci.org](http://www.pci.org) and click on the 2014 Design Awards link under the What's New section for more information and to make a submission.

**2014 Call for Papers Abstracts due JANUARY 24, 2014!**



***PCI Convention and National Bridge Conference***  
September 6-9, 2014 • Washington D.C.

PCI is accepting abstracts for technical papers to be presented at the 2014 PCI Convention and National Bridge Conference in Washington D.C. Abstracts and papers will be peer-reviewed and accepted papers will be published in the proceedings.

The PCI Convention and National Bridge Conference is the premier national venue for the exchange of ideas and state-of-the-art information on precast concrete design, fabrication, and construction. The event attracts an average of 1,000 participants each year and provides an outstanding opportunity for networking, education, and sharing ideas. Don't miss out on this excellent opportunity to share your knowledge—submit your abstract today!

Since this will be PCI's 60th anniversary, the event will be focused on celebrating 60 Years of Success and innovation in the precast concrete structures industry.

While abstracts may be submitted on any relevant topic to the precast concrete industry, abstracts that support the event theme will be given preference.

# Innovation Drives Expansion

Beam, Longest and Neff expands from its Indiana base with new concrete techniques that create distinctive designs and lower costs

by Craig A. Shutt

An impressive reputation in its home state of Indiana has gained Beam, Longest and Neff (BLN) a long list of repeat customers at the state and local level. Now, the company has begun to grow aggressively, leveraging its value-engineering expertise and ability to find creative solutions to demanding challenges.

“We receive 90 to 95% of our business from repeat customers because of the high quality of service we provide,” says James Longest, president of the Indianapolis-based firm. “Because of the quality of the staff we have retained, and our focus on internal quality control, we produce a product that exceeds our customers’ expectations.”

Adds Thomas Longest, executive vice president, “We pride ourselves on

creating a product with a more efficient and cost-effective solution than any other company could produce.”

Now, they are using their reputation and diverse expertise to gain customers in other geographic regions. “We are absolutely in growth mode,” says Thomas Longest. “We are looking to expand our geographic footprint with great success, while continuing to explore strategic hubs for operational efficiencies.”

The firm currently operates from four offices and could add more, Thomas Longest says. “We will open new offices when they are needed, but we lean extensively on our home office.” That staff, he notes, has working experience with 38 departments of transportation (DOTs).

## Efficient Designs Dominate

Its base of repeat customers is notable because many designs are not the large, signature bridges that other firms use as launching points. “Showcase bridges are not the majority of what we do,” says Michael L. McCool Jr., bridge department manager. “We create designs that are efficient, low cost, and durable, and that gains us notice.”

An example is the Rockport Road Bridge over Clear Creek in Monroe County, Ind. The bridge was designed as a single-span, prestressed concrete I-beam structure with integral end bents and a concrete deck. The design eliminated any piers in the channel and minimized channel work.

The project was a state finalist in the Engineering Excellence Competition of



The replacement Rockport Road Bridge over Clear Creek in Monroe County, Ind., is a single-span, prestressed concrete I-beam bridge with integral end bents and a concrete deck. All Photos: Beam, Longest and Neff.

the American Council of Engineering Companies (ACEC) in Indiana. "It had a conventional design and wasn't a showcase, but it was exactly what the client needed," McCool says. "It was a neat, clean project."

Alternatively, there are more complex projects, such as the State Route 66 Bridge over Green River Road in Evansville, Ind. For this project, the designers replaced an existing steel-girder bridge with 317-ft-long twin structures consisting of curved, three-span, post-tensioned concrete bulb tees with integral end bents. The interior supports consist of integral post-tensioned concrete straddle bents. This unique design was necessary due to the single-point interchange that the bridge spanned.

Construction of the State Route 66 Bridge over Green River Road was phased to maintain two lanes of traffic at all times. The project won an honor award in the Engineering Excellence Competition from the ACEC of Indiana and a 2005 PCI Design Award.

"This was a challenging project, because it had MSE [mechanically stabilized earth] walls used on the approaches and in an urban setting with a lot of right-of-way restrictions," McCool explains. "We were able to build the bridge at a tight interchange with a high volume of traffic without rebuilding the MSE walls. We minimized the construction depth with the post-tensioned bulb tees and were able to follow the curves of the roadway and walls. It added complexity, but it best served the setting."

### Large-Scale I-69 Project

At the other end of the scale, the firm was selected to help develop a new I-69 corridor from Indianapolis to Evansville, with portions still under construction. BLN's involvement includes 49 bridges, with 15 under a design-build delivery format and eight that were value-engineered, which in Indiana is called a cost reduction incentive (CRI) design. The construction packages included multiple bridges, interchanges, and new roadways.

The firm started its work on the project by designing two twin bridges on a tight deadline, one of which they were able to reduce from the planned



Designed to reduce traffic congestion, the State Route 66 Bridge over Green River Road in Evansville, Ind., replaced a single-span steel bridge with a curved, three-span, post-tensioned concrete bulb-tee design.



The construction of the State Route 66 Bridge over Green River Road was phased to maintain two lanes of traffic in each direction.

13-span design to a 10-span structure without changing the roadway profile. "That impressed DOT officials, and we worked our way up the interstate corridor from there," says McCool.

Value-engineering or CRI projects are becoming more commonplace in Indiana, McCool notes. "The CRI concept leads us to analyze superstructures and use more efficient designs, which often allows us to eliminate a beam line or more," he says. "We internally review everything closely to be sure that what we put out to bid is what the contractor will build."

The CRI concept was used on a section of the I-69 project, which originally was designed to carry the highway over State Routes 61/56 in Pike County. BLN's

value-engineering proposal flipped the design so the state routes went over I-69. This design necessitated revising drainage calculations, road profiles, ramps, and other factors.

But the redesign eliminated one bridge and simplified the interchange, resulting in only a single bridge design. The bridge consisted of a two-span continuous, composite, prestressed concrete hybrid bulb-tee beam superstructure constructed with a 16.5-degree skew. MSE retaining walls shortened the span lengths to 96 ft and contributed to the \$5.5-million reduction in cost at the interchange. Overall, the CRI produced savings of nearly \$10 million on the initial \$60-million bid. "The redesigns reduced the size of the project overall



By flipping the original design, Beam, Longest and Neff used Indiana's cost reduction incentive option to eliminate a bridge from the interchange, saving considerable time and money.

by a significant amount, resulting in considerable savings," says James Longest.

### Design-Build Grows

Indiana has been bundling more projects, as happened on I-69, to create better design options, notes James Longest. "I believe in the not-too-distant future, we'll see most projects focused on a P3 [public-private partnership] or design-build basis. That is definitely the direction that states are heading."

The design-build approach encourages innovations, and BLN takes advantage of these opportunities. "Design build and CRI have led us to new strand technologies and to using lightweight concrete to create longer beams to eliminate spans," says McCool. The firm often uses a specialized girder shape developed by Indiana, and similar to the

Nebraska bulb tee. "It offers the same concept and can compete against steel options from a depth standpoint."

The designers also are looking closer at the use of lightweight concrete and internally cured concrete. BLN has had success with a research project conducted by Purdue University, which is evaluating options for internally cured concrete. "It is getting more interest in the state and is becoming a new tool in the designer's toolbox," says McCool. The new concrete provides a unique mix design with aggregates that retain water, which may reduce the overall amount of shrinkage cracking.

The research program is conducting a test in rural Monroe County, where side-by-side, single-span, adjacent box-beam structures are being monitored for surface shrinking and cracks. "I

like the results we're seeing so far. It offers promise for better long-term serviceability, and it's performing well to date."

Reducing life-cycle costs has become a key focus, as owners realize the full extent of benefits from more durable structures, adds James Longest. "Clients especially like that we can save money upfront, as well as over the life of the project. Concrete becomes even more competitive when life-cycle costs are taken into account. As we apply new techniques and innovations, that will become even more true."

**'Concrete becomes even more competitive when life-cycle costs are taken into account.'**

BLN stays current with design techniques in many ways, including technical staff participation on several technical committees. "I bring back a lot of new ideas that are on the cutting edge of design from the meeting discussions, and we use as many as possible in our design plans. We like to stay out in front on AASHTO updates and local code revisions," says McCool.

An example can be seen in the design-build project its Colorado office completed that replaced five bridges along I-25 south of Fountain, Colo. The bridge design features two 71-ft-long spans comprising adjacent, prestressed concrete box beams. Due to the high volume of traffic, Colorado officials required a short construction schedule that minimized traffic impact. The design-build team looked for ways to accelerate construction to disturb traffic for only 15 days while replacing the five bridges.

The designers used as much precast concrete as possible and allowed concrete closure placements on the

A design-build delivery method was used to replace five bridges along I-25 south of Fountain, Colo. The design allowed the high-volume bridges to be constructed with impact to traffic lanes for only 15 days.





Fountain County Bridge No. 7 in Indiana used Beam, Longest and Neff's bridge design, survey, environmental, and right-of-way services.

bridge deck while under traffic. This resulted in only single-lane closures of the northbound lanes. Some of the acceleration techniques, such as precast concrete approach slabs and joint connections, had not been used before in the state, but the concepts were derived from recent PCI publications.

Providing high constructability and lower costs often are accomplished due to the designers' familiarity with what works best in each location, notes James Longest. "Our designs result from having intimate knowledge of the local design manuals, as well as a particular state's requirements along with contractor's construction methods."

### Three Generations of Leadership

Beam, Longest and Neff (BLN) was founded in 1945 as the partnership Pierce, Gruber and Beam, which was incorporated in 1953. In 1957, the firm formed Highway Surveys Inc., which was merged with the parent company 10 years later, forming BLN.

Over the years, ownership transitioned within the founding family from Hubert Longest Sr. to Hubert Longest Jr. and most recently to James and Thomas Longest. In that time, it has expanded into a full-service engineering firm with 100 employees and four offices, comprising the corporate headquarters in Indianapolis; Charleston, W.Va. (1984); Louisville, Ky. (1999); and Denver, Colo. (2010).

### Creating Value in New Ways

Creating value can mean more than simply saving initial costs, notes Thomas Longest. For instance, a 24-ft-wide bridge may meet traffic requirements, but if the structure is used by 30-ft-wide farm equipment, it may make more sense to widen it. "Making it that much wider will save money long-term from a maintenance standpoint and better serve the community."

Value also comes from reducing construction time, which improves safety. That often leads to repair and rehabilitation projects, which can speed turnaround and reduce costs. "Clients are looking to build more projects with fewer dollars, so they very much are in preservation mode," says Thomas Longest. "We are doing more rehabilitation projects, as well as more deck, joint, and rail replacements today."

Rehabilitation projects tend to be smaller in scope than replacement projects, McCool notes, but they can become complex if drawings are incomplete or work is being done in phased construction under traffic. "If we have to speculate on what has been built or work around maintaining traffic, it can become a more challenging type of project."

### Cost-Effective Aesthetics

Aesthetics also are becoming more significant in bridge designs, notes Thomas Longest. "Owners are interested in improved aesthetics, especially in urban areas, although less so in rural areas. We usually discuss options for creating cost-effective aesthetic designs."

The biggest obstacle is the mindset that adding design elements or decorations will be costly, he says. "Owners don't realize there are many effective solutions for making bridges more interesting without making them cost more. Our first choice is always to use formliners and stains; in one instance, we replicated the look of Indiana limestone, which was very popular near the bridge. We also use decorative railings a lot. Once clients see what's possible, they embrace it."

In some cases, the firm creates samples or renderings to help visualize the end

result. They also create partnerships with local planning authorities (LPAs) where the bridge is located. "The LPA often will partner with the client to fund part or all of the aesthetic improvements being considered."

**'Owners don't realize there are many effective solutions for making bridges more interesting without making them cost more.'**

Types of bridges also are evolving, with more interest in pedestrian bridges than ever before, says McCool. "We are adapting as new bridge options become available by staying abreast of new design technology and practices. Our goal is to tighten everything down in advance and create close communication with our partners, including the precasters. We want to have all the details understood so the bridge we're designing provides the most constructable option possible." 

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



Beam, Longest and Neff provided bridge design and other services for the Hamilton County Bridge No. 230 in Indiana.

# The AASHTO Manual for Bridge Element Inspection

by Matthew M. Farrar, Idaho Transportation Department and Barton Newton, California Department of Transportation



The need of bridge owners to effectively assess the condition of their bridge assets in order to efficiently manage their preservation, repair, rehabilitation, and replacement has been ever present. With the introduction of the 2013 *AASHTO Manual for Bridge Element Inspection* (AASHTO MBEI), 1<sup>st</sup> Edition, the American Association of State Highway and Transportation Officials (AASHTO) has developed a state-of-the-art tool for assessment of the nation's bridges.

## Background

In the early 1990s the Federal Highway Administration (FHWA)—working collaboratively with several states—introduced the concept of more accurately assessing individual components or elements of bridges and how they deteriorate. This information is essential to bridge management.

Subsequently, AASHTO created the concept of bridge elements with the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements*, First Edition (1998). This inspection approach improves upon that required by the National Bridge Inspection Standards (NBIS) in that individual bridge elements are quantified and

their condition assessed. For example, individual components of a concrete arch bridge—such as beams or stringers, floor beams, spandrel columns, arches, their concrete protective coatings, and concrete reinforcing steel protective systems—are quantified and their conditions are assessed rather than simply giving one condition assessment to the entire superstructure of an arch-type bridge as would be done with the NBIS.

As the use of element-level inspection techniques proliferated, the need for improvements became identified. In 2011, AASHTO created the *AASHTO Guide Manual for Bridge Element Inspection* (GMBEI), 1<sup>st</sup> Edition. This manual contained many improvements and enhancements, such as:

- changes in the measurement units of decks and slabs,
- development of the wearing surface element,
- standardization of the number of element states,
- development of the protective coating element, and
- incorporation of expanded element smart flags.

The goal of the AASHTO GMBEI was to completely capture the condition of bridges in a simple way that could be standardized across the nation while providing the flexibility to be adapted to both large and small agency settings. Michael B. Johnson of the California Department of Transportation and Paul Jensen (retired) of the Montana Department of Transportation were fundamental to the development of the GMBEI.

After the introduction of the AASHTO GMBEI, bridge inspectors and bridge asset managers from bridge owner agencies, the FHWA, consultant inspection firms, and training instructors suggested improvements. The result is

now presented as the 2013 AASHTO MBEI.

## AASHTO MBEI

The AASHTO MBEI comprises 245 pages and has been divided into three sections and five appendices. Section 1, Background, discusses the philosophy behind element level condition assessment and multiple distress paths within the defined condition states. The multi-path distress language provides the means to fully incorporate all possible defects within the overall condition assessment of the element. The overall condition of the element can be utilized in this aggregate form, or broken down into specific defects as desired by the agency for bridge management system (BMS) use.

In Sections 2 and 3, the AASHTO MBEI provides a comprehensive set of bridge elements that are designed to satisfy the needs of all agencies. The element set presented includes two element types identified as national bridge elements (NBEs) and bridge management elements (BMEs). Also a framework for agency developed elements has been created to provide an agency with the ability to define custom sub-elements in accordance with the NBEs or BMEs or for agency elements not defined in the AASHTO MBEI. All elements are assigned a standard number representing one of four condition states: good, fair, poor, and severe.

NBEs represent the primary structural components of bridges necessary to determine the overall condition and safety of the primary load carrying members. NBEs are a refinement of the deck, superstructure, substructure, and culvert condition ratings defined in the FHWA's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*. Additional elements included in this section are bridge rail and bearings. NBEs are designed to remain consistent from



A worker inspects under the State Highway 3 Bridge over Childs Creek in northern Idaho. All Photos: Idaho Department of Transportation



An under-bridge inspection truck is used at the site of State Highway 78 over Rabbit Creek in southwest Idaho.

## Acronyms

Many acronyms are used in this article. Their definitions are provided below:

BME = bridge management element

BMS = bridge management system

GMBEI = Guide Manual for Bridge Element Inspection

MBEI = Manual for Bridge Element Inspection

NBE = national bridge element

NBIS = National Bridge Inspection Standards

agency to agency across the country, to facilitate and standardize the capture of bridge element conditions at the national level. In order to capture the diversity of new element design types and materials, many elements in this category have an “other” type element defined.

BMEs include components of bridges such as joints, wearing surfaces, and protective coating systems and deck/slab protection systems that are typically managed by agencies utilizing a BMS. BMEs are defined with a recommended set of condition assessment language that can be modified to suit the agencies needs as these elements are not intended to be utilized for the purposes of national policy making. BMEs defined within the AASHTO MBEI were purposefully left fairly general in nature to provide

the flexibility to develop agency specific elements that best suit the local bridge management practices. Agencies may choose to develop additional BMEs as necessary following the agency-developed element conventions discussed in appendix A of AASHTO MBEI. When considering additional elements, the agency should consider such factors as element performance, deterioration rates, feasible actions, and preservation costs, as well as the practical considerations of training and inspection costs.

The elements presented in the AASHTO MBEI provide the flexibility for an agency to define custom elements in accordance with the defined element framework that may be sub-elements of NBEs or BMEs, or may be agency defined elements without ties to the elements defined in this manual. By defining a comprehensive set of bridge elements necessary for robust bridge management and the minimum set of elements necessary to assess the condition of primary components of bridges, the AASHTO MBEI provides a flexible element set that can be tailored to the needs of all agencies.

The new elements contained within the AASHTO MBEI have been introduced into AASHTOWare™ Bridge Management software BrM (formerly Pontis), as well as other bridge management systems. The new elements and the AASHTO MBEI as a whole are foreseen to provide greatly improved tools to bridge owners and will enable them to more effectively manage their bridge assets. **A**

COMMERCIAL & STRUCTURAL

# STRENGTH

TYFO® FIBRWRAP® SYSTEMS

**STRENGTHEN VITAL**

**INFRASTRUCTURE SUCH AS**

**BRIDGES, PIPELINES, BUILDINGS**

**AND OTHER STRUCTURES.**



The Tyfo® Fibrwrap® system can be used to add structural properties to bridges so they can carry heavier loads, restore damaged concrete on waterfront structures, repair and strengthen pipelines or reinforce building foundations and bridges to withstand seismic and blast loads. This light-weight, low-profile structural material provides the equivalent structural strength compared to heavier and obtrusive concrete and steel solutions.

Fyfe engineers provide personalized technical support with comprehensive design and specification support packages with no obligation and at no cost.



*Fyfe Company is proud to be a part of the Aegion Commercial & Structural platform.*

© 2013 Aegion Corporation

## PROJECT

# Jeremiah Morrow Bridge

Ohio's tallest bridge spans the scenic Little Miami River

by Karen Cormier, T.Y. Lin International; Murat Aydemir, HNTB; Ryan Cocco, Kokosing Construction Company Inc.; and Daniel P. Mendel, Ohio Department of Transportation

The tallest bridge in Ohio and the first cast-in-place, concrete segmental box-girder structures owned by the Ohio Department of Transportation (ODOT) began construction over the scenic Little Miami River in June 2010. The six-span, twin bridges have three 440-ft-long main spans, one interior span of 416 ft, and side spans lengths of 229 and 270 ft. The top of deck is elevated 239 ft above the valley floor. A variable-depth, single-cell, box-girder cross section with cantilevered deck overhangs provides a 52-ft-wide bridge deck to accommodate two 12-ft-wide traffic lanes, a 12-ft-wide emergency

lane, and two shoulders with widths of 6 and 10 ft. The addition of two traffic barriers results in a top flange width of 55 ft.

All pier substructure elements are outside the Little Miami River. Four of the five piers are monolithic with the box girder superstructure; one exterior pier and both bridge abutments support the superstructure on sliding bearings. The hollow-box monolithic pier sections vary in height from 24 to 129 ft, with an additional upper 65 ft section of the piers formed in a split-leaf configuration

and a 25-ft-deep pier section sits on top of all four piers.

The bridge is supported on either driven steel HP piling or reinforced concrete, cast-in, drilled-hole (CIDH) shafts, depending on site geology. The HP14x89 piles were driven to an ultimate bearing of 314 tons; perimeter piles in the longitudinal direction were battered. Eight-foot-diameter drilled shafts provided end bearing capacity of 45 tons/ft<sup>2</sup>. Smaller HP14 pile sections and 3-ft-diameter drilled shafts were utilized at the rear and forward abutments, respectively.

The new bridges replace two existing steel truss structures that were deemed too expensive to maintain and rehabilitate. Traffic flow in both directions needs to be maintained at all times on this important I-71 corridor connecting Cincinnati and Columbus. Traffic will be re-routed from the existing northbound bridge to the first bridge, which is constructed between the two existing steel structures. Demolition of the existing northbound bridge will then commence followed by construction in its place. When completed, northbound traffic will be directed onto the second bridge,

The location of these bridges over the Little Miami River, a National Scenic Waterway, necessitates an environmentally-sensitive method of construction to minimize impact to the lush river valley. The contractor also needed to meet uniform concrete appearance requirements for the structural elements. Rendering: HNTB.



## profile

### JEREMIAH MORROW BRIDGE/I-71 / WARREN COUNTY, OHIO

**BRIDGE DESIGN ENGINEER:** HNTB, Chicago, Ill.

**PRIME CONTRACTOR:** Kokosing Construction Company Inc., Fredericktown, Ohio

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

**OTHER SUBCONSULTANTS AND SUBCONTRACTORS:** OmniPro Services LLC, Canton, Ohio; T.Y. Lin International, San Francisco, Calif.; Corven Engineering Inc., Tallahassee, Fla.; CTL Engineering, Columbus, Ohio.

southbound traffic onto the first bridge, and the remaining original bridge will be dismantled.

## Design Features and Considerations

The superstructure box girder depth varies from 12 ft at midspan to 25 ft at the pier, with a bottom soffit thickness varying from 9½ in. in the midspan region to 3 ft 8 in. at the pier. The inclined box girder web walls are 1 ft 6 in. thick, and support a deck slab of variable thickness. The deck is cantilevered 12 ft 6 in. from the webs; this overhang varies in thickness, curving gently into the web/deck junction. Design 28-day concrete compressive strength for the superstructure is 6 ksi.

Under balanced cantilever construction, each 16-ft-long, box girder segment is post-tensioned with internal longitudinal cantilever tendons comprised of twelve to twenty-two 0.6-in.-diameter strands stressed from one end. Four-strand tendons in flat ducts spaced on average at 2 ft 8 in. intervals provide deck post-tensioning in the transverse direction.

Internal post-tensioning is further utilized for continuity once closure between cantilever superstructure tips is achieved. Finally, external post-tensioned tendons housed within high-density polyethylene ducts and anchored inside the box girder segment at the pier table and intermediate diaphragms are stressed to add



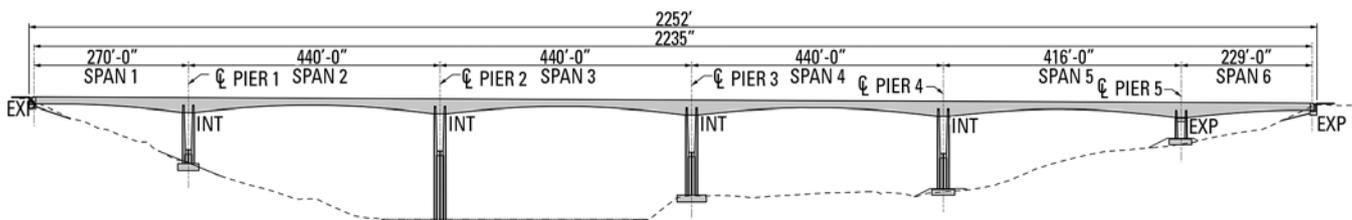
Transverse four-strand tendons in the top slab and longitudinal post-tensioning were used to achieve “zero-tension” criteria under service load conditions. Photo: Jeff Weiler, OmniPro Services.

further capacity for live load as well as time-dependent prestress losses and moment redistribution.

The bridge piers are hollow 20 by 21 ft boxes with 3-ft-thick reinforced concrete walls. A solid diaphragm serves as the transition from a hollow box to a split-leaf twin wall arrangement for the upper 65 ft of the pier columns. Base access into the pier column box allows for inspection from a permanently mounted ladder system. Inspection of the surface of the twin walls will be performed using rappelling methods from access

hatches through the bottom slab of the pier table.

Tall and flexible bridge piers, monolithically connected to the superstructure, provide an element of geometric control complexity that relies on precise time-dependent deflection predictions. Long-term moment and force redistribution requires an introduction of horizontal displacement at the top of the columns to compensate for a portion of the long-term creep and shrinkage movements that will affect primarily the outer-most columns of pier 1 and 4 columns.



Bridge elevation. Drawing: HNTB.

## OHIO DEPARTMENT OF TRANSPORTATION, OWNER

**BRIDGE DESCRIPTION:** Twin six-span, post-tensioned, single-cell, cast-in-place concrete, segmental box girder structures each 2252 ft long with an elevation of 239 ft above the valley floor

**STRUCTURAL COMPONENTS:** Variable-depth (12 to 25 ft) box girders; one-hundred twenty-two 16-ft-long, cast-in-place segments per bridge; deck width of 55 ft; 31 million ft of 0.6-in.-diameter, seven-wire post-tensioning strand in both bridges. Tallest pier is 219 ft.

**BRIDGE CONSTRUCTION COST:** \$90,188,005, including approach roadwork

The bridge plans indicate a horizontal jacking force and sequence of concrete closure placements that initiate from the center of span 3 and proceed to the exterior spans. The horizontal jacking force was determined from time-dependent computer modeling assuming parameters of concrete properties, schedule progression and rate of production, and estimated foundation soil spring stiffness. However, the primary goal of the horizontal jacking procedure is to initiate a somewhat arbitrary target displacement to compensate for part of the long-term losses due to creep and shrinkage.

## Construction

All concrete incorporated into the structure was air-entrained and required to meet a strict permeability specification of 2500 coulombs at 60 days. The mixture proportions include a high-range water-reducing admixture and a set-retarding admixture to optimize workability. Fly ash was used as 33% of the total cementitious materials for the superstructure concrete and 50% for the substructure elements defined

as mass concrete. All reinforcing steel in the structure—footings, piers, superstructure, barriers, and abutments—is epoxy coated.

When completed, the 216-ft-long open cantilevers required a total of 52 longitudinal cantilever tendons stressed to 40,868 kips total jacking force at 75% of the ultimate tensile stress. Strict anti-corrosion measures necessitated tendons being grouted within 20 days of being placed in the ducts. Due to low ambient temperature unfavorable to grouting operations, segmental construction was not continued during the winter months.

The grouting plan provided 100% borescope inspection of all post-tensioning anchorages and high points of duct profile. The grouting crew worked in conjunction with the quality inspection team to provide consistent grout results with measures to ensure that the ducts were fully filled with sound material.

In order to ensure that the horizontal jacking displacement requirements

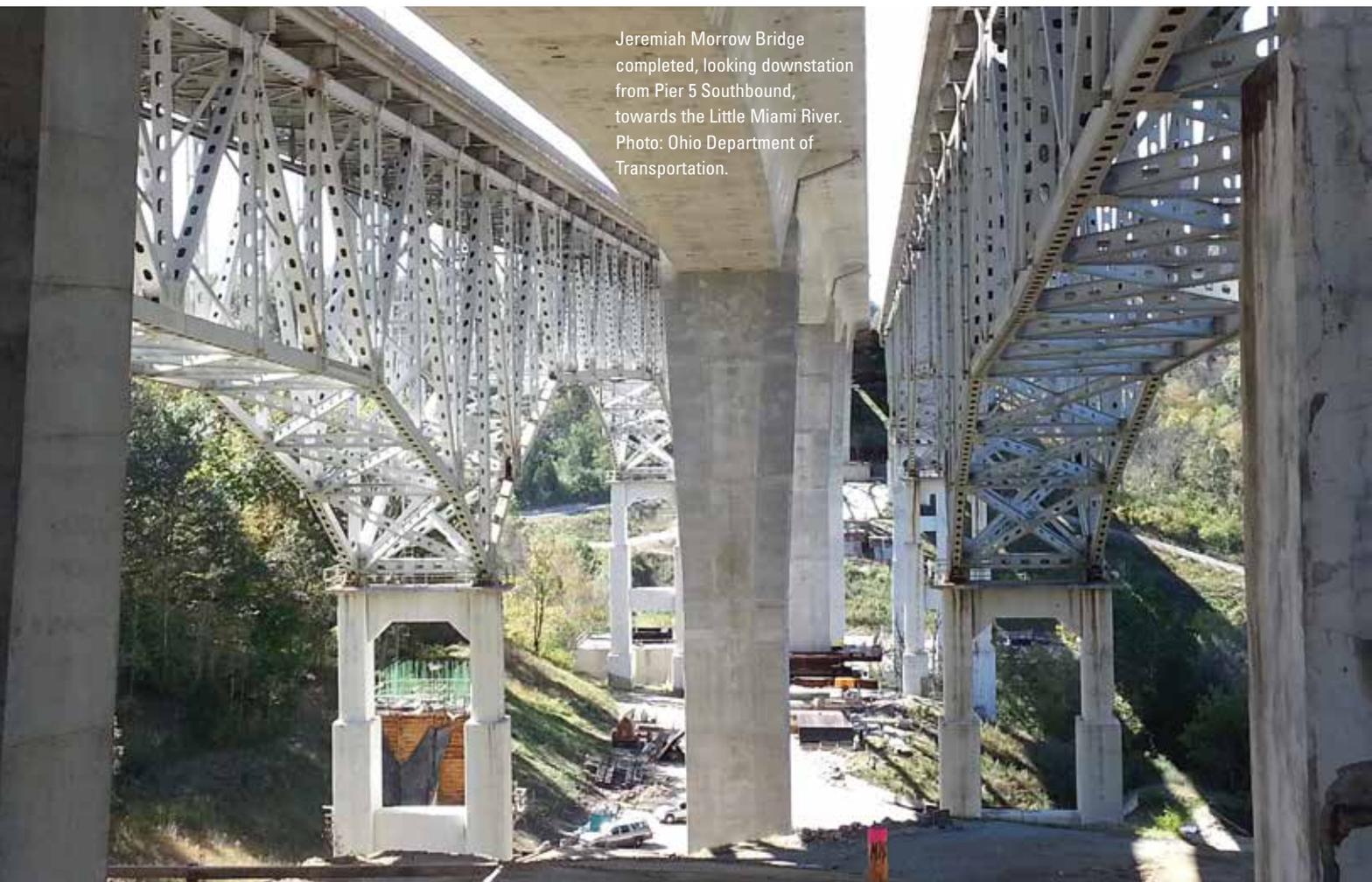
## The grouting plan provided 100% borescope inspection of all post-tensioning anchorages.

were met, a deflection monitoring system of tiltmeters was mounted on the pier columns to measure the resulting movement in real time during the horizontal jacking procedure. The monitoring system also provided valuable pier bending and rotation data during the segmental casting cycle for casting curve adjustments.

A latex-modified concrete overlay is used on the deck for additional corrosion protection. **A**

---

Karen Cormier is a segmental specialist with T.Y. Lin International in San Francisco, Calif. Murat Aydemir is a project engineer with HNTB in Chicago, Ill. Ryan Cocco is a project manager with Kokosing Construction Company Inc. in Fredericktown, Ohio. Daniel P. Mendel is a resident engineer with the Ohio Department of Transportation in Mason, Ohio.



Jeremiah Morrow Bridge completed, looking downstation from Pier 5 Southbound, towards the Little Miami River. Photo: Ohio Department of Transportation.

# AESTHETICS COMMENTARY

by Frederick Gottemoeller



Building a major bridge over a wide and deep scenic valley is a challenge that most bridge designers would welcome. The first goal must be to place a bridge in the scene that, at the least, does not detract from the valley. The more important goal is to place a bridge that actually adds to the site's scenic quality, that becomes an asset to the site, and that fits the site so well that it looks like the bridge has always been there. The designers of the Jeremiah Morrow Bridge rose to that challenge.

Many of the positive qualities of the new bridge can be recognized by comparing it to the previous truss bridge. In most settings, and certainly in scenic ones, visual simplicity is a virtue. However, the truss superstructure is complicated, with multiple members at multiple angles to each other. Jeremiah Morrow's concrete box superstructure is a single modulated shape. The existing piers are stepped, with two columns that abruptly change thickness as they rise, connected by multiple cross struts. They call to mind tall, thin wedding cakes. Jeremiah Morrow's new piers are single tapered shapes, forked at the top. Because of this simplicity, the new bridge will not engage the eye as much as the existing bridge. The mind will be freed to engage with the scenic virtues of the site.

In a natural environment, one is surrounded by trees. Trees naturally embody the effect of the forces on them: branches are thickest at their origins and thinnest at their tips. Jeremiah Morrow's girders are thickest where the forces are the greatest—over the piers—and thinner everywhere else. Jeremiah Morrow's piers are widest where they meet the girder, then taper slightly before they head to the ground. Trees take these shapes because that uses resources as economically as possible. Jeremiah Morrow does the same, and this congruence is one source of its aesthetic appeal.

The openings at the tops of the piers are there to create some longitudinal flexibility for dealing with thermal and long-term stresses, but have the aesthetic effect of adding points of interest and a sense of lightness to the bridge. This is another of those instances when structural goals and visual goals can be served by the same feature, making for a design "twofer". The faces of the piers are divided into three vertical planes set at slightly different angles. Each plane reflects light differently. The piers are visually divided into three vertical strips of differing brightness, making the piers look thinner than they actually are.

None of the features described above could have added significant or even recognizable cost to the bridge. All are the result of careful selection of shapes and proportions for elements that had to be there anyway. Ohio has a beautiful new bridge.

**BUILDING TOMORROW'S BRIDGES. TODAY.**

*Corrosion Protection – No Coatings*  
*AASHTO Approved for Grade 100*

For more information  
866.466.7878  
[www.mmfx.com](http://www.mmfx.com)

**MMFX<sub>2</sub>** TODAY'S STEEL STANDARD™  
**Uncoated Corrosion-Resistant | High-Strength | Lowest Life Cycle Cost**

## PROJECT

# SC 802 over the Beaufort River and Intracoastal Waterway Bridge

Barge collision necessitates new bridge, more-resilient design

by Edward H. Stehmeyer III, Collins Engineers Inc.

In late April 2007, a barge carrying a crane with its boom partially raised struck the 4200-ft-long, two-lane McTeer Bridge over the Beaufort River and Intracoastal Waterway in Beaufort County, S.C. Two steel girders on the southern-most portion of the bridge spanning the navigable channel were destroyed, and a third girder was seriously damaged.

The damaged McTeer Bridge was one of only two bridges for more than 40,000 low-country drivers to travel from Lady's Island, and the other surrounding islands, to the mainland of Port Royal. The full and partial closures of the bridge for emergency repairs

created substantial traffic problems for almost three months. The temporary inconvenience highlighted the inability of the existing transportation infrastructure to handle an increase in the amount of traffic should an evacuation from the islands occur prior to a hurricane.

Prior to the impact at the bridge, the residents of Beaufort County had voted to enact a local sales tax upon themselves to fund future infrastructure projects that would be effective in May 2007. Following the impact and subsequent repairs to the McTeer Bridge, the decision was made to widen the approaching roadway and build

a new parallel "sister" bridge to the existing McTeer Bridge. The new bridge project, SC 802 over the Beaufort River and Intracoastal Waterway, was to be the recipient of \$34.6 million of those local sales tax generated funds.

### New Bridge Needed

The Beaufort County Engineering Division selected a bridge design engineer to provide project management and engineering design services for the construction of a new 4211-ft-long, two-lane, high-level bridge carrying SC 802 over the Intracoastal Waterway and adjacent protected marsh wetlands, and the widening of an additional 1.7 miles

Completed SC 802 over the Beaufort River and Intracoastal Waterway Bridge. Photo: Collins Engineers Inc.



## profile

### SC 802 OVER THE BEAUFORT RIVER AND INTRACOASTAL WATERWAY BRIDGE / PORT ROYAL AND LADY'S ISLAND, SOUTH CAROLINA

**BRIDGE DESIGN ENGINEER:** Collins Engineers Inc., Charleston, S.C.

**PRIME CONTRACTOR:** United Contractors LLC, Great Falls, S.C.

**PRECASTER:** Standard Concrete Products, Savannah, Ga., a PCI-certified producer

**OTHER SUPPLIERS:** S&ME Inc., Mt. Pleasant, S.C.; Tidewater Environmental, Johns Island, S.C.; Dennis Corporation, Columbia, S.C.; OLH Inc., Columbia, S.C.; Woolpert, Charleston, S.C.; and THC Right of Way Services Inc., Columbia, S.C.

of adjoining roadway. The bridge was designed on an accelerated 14-month schedule. Bid documents were ready in January 2009 and construction on the new bridge began in September 2009.

This Beaufort County-funded, South Carolina Department of Transportation (SCDOT)-owned and -operated project had several key tenets. Examples of those tenets were affordability to the county, maintainability for the SCDOT, and improvement of the hurricane evacuation route in the area. With the community putting up the funds for this critical infrastructure project, the construction budget was a key issue, as well as incorporating local residents' ideas expressed at numerous public information meetings.

A bridge type study was conducted to determine feasible and desirable alternatives and to incorporate improvements, such as bicycle and pedestrian access and aesthetics to complement the existing bridge. In addressing all of these points, the bridge design team focused on employing sustainable materials through an all-concrete design while satisfying the inherent hazards of the project location. The use of an all-concrete structure yielded construction cost savings and created future maintenance savings.

**The use of an all-concrete structure yielded construction cost savings and created future maintenance savings.**

Examples of these savings are eliminating the need to paint steel girders over long waterway spans and having fewer substructure units in the waterway. The resulting superstructure consists of 79- or 96-in.-deep, bulb-tee beams spaced at 9 ft 6 in. for the span lengths of 135, 140, and 170 ft. The girders support an 8-in.-thick, cast-in-place concrete deck. Reinforced concrete flat slabs are used for the thirty-five 30-ft-long spans over the low-level marsh wetland crossings.

### Resiliency Required

A challenge posed by the bridge site was the need for a resilient bridge design with an end product capable of withstanding various extreme events including earthquakes (inertia loading and liquefaction), hurricane force winds and associated storm surge, flood and high currents (scour), and vessel impact. To tackle these issues, the design team employed a multi-hazard design approach using realistic combinations of extreme event loadings that were consistent with the latest Federal Highway Administration research.

The balancing act presented when considering the strength and ductility to withstand a seismic event in conjunction with a scoured and un-scoured channel bottom condition was examined. In particular, the displacement demands were determined through elastic dynamic (modal) analyses and the substructure displacement capacity was determined through the use of non-linear static (pushover) analyses. And, while vessel impact due to barge trains and small cruise ships was considered separately through a probabilistic hazard design, the strength and ductility implemented to withstand earthquake loading lent itself to the bridge's resistance to vessel impact and other environmental lateral loadings.



Record-setting, 96-in.-deep main-span; bulb-tee beams being set. Photo: United Contractors.

### Substructure

The resulting substructure design incorporated prestressed concrete pile bents for the low level marsh wetland crossings, and isolated reinforced concrete drilled shaft bents and drilled shaft groups supporting reinforced concrete waterline footings and hammerhead piers for the high-level spans over the main waterway. Another unique design challenge for the project was the 7- to 8-ft daily tide swing. Through the use of permanent precast concrete soffit elements to construct the waterline footings, construction time savings were realized.

### Aesthetics

The design process included aesthetic considerations in conjunction with traditional structural demands, since the new bridge parallels the existing McTeer Bridge. While longer spans for the new bridge would have been possible with the use of newer technology like spliced bulb-tee concrete girders, the public desire to have the new bridge resemble the existing bridge remained strong. Span arrangements were therefore kept similar to the existing bridge, with some pier locations eliminated to minimize substructure elements in the waterway and streamline the bridge profile to stay fairly symmetrical with the existing bridge, creating a "twin" or "sister" bridge appearance.

## SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION, OWNER

**BRIDGE DESCRIPTION:** A 4211-ft-long, high-level bridge with two lanes for vehicular traffic, a pedestrian walkway, and shared bicycle lanes. The bridge's main spans of 170 ft are the longest single-piece, precast concrete beam spans in the state using 96-in.-deep, prestressed concrete bulb-tee girders.

**STRUCTURAL COMPONENTS:** Permanent precast concrete soffits; 15 cast-in-place concrete waterline footings; 11,810 ft of 79-in.-deep, modified, prestressed concrete, bulb-tee beams; 3875 ft of 96-in.-deep, prestressed concrete, bulb-tee beams; and a cast-in-place deck

**BRIDGE CONSTRUCTION COST:** \$34.6 million (\$176.70/ft<sup>2</sup>)

**AWARDS:** 2013 PCI Design Award: Best Bridge with Spans over 150 ft and ACEC-SC Engineering Excellence Awards: 2012 Finalist



Flat slab bridge section piles and deck slab beginning to take shape from the shore at Lady's Island. Photo: Aaron Goldberg, S&ME Inc.

## Superstructure

The superstructure design included the use of 96-in.-deep, prestressed concrete bulb-tee girders for the three 170-ft-long main spans over the Intracoastal Waterway. The bridge design team selected prestressed concrete girders to meet the overall project tenets of maintainability for the SCDOT. Reinforced concrete hammerhead piers were used to mimic the overall profile of the existing piers. Whereas pile group foundations were present on the existing structure, drilled shaft construction was used on the new bridge to resist the high lateral demands from seismic, wind, and vessel collision hazards. The hammer head pier stems were also treated with a fluted form liner to improve aesthetics over a plain solid concrete face.



Placing deck concrete for the new structure. Photo: United Contractors.

## The bridge design team selected prestressed concrete girders to meet the overall project tenets of maintainability for the SCDOT.

### Sustainability

The design team's focus on sustainability also led to investigating sources of bridge components and designed structural elements that could be locally produced, shipped, and constructed cost effectively. While the 170-ft-long girders set a record becoming the longest single-piece, prestressed concrete girder spans in South Carolina, they are a conventional and readily available construction method that did not require specialty subcontractors to erect the beams.

The beams were specified for an initial and 28-day concrete compressive strength of 7 and 10 ksi, respectively.

The large precast concrete girders were produced in Savannah, Ga., less than 50 miles from the project site and also located on the Intracoastal Waterway. This location facilitated shipping beams directly from the plant to the site on barges, which saved on transport costs and eliminated the need for special overland heavy load permits.

The new SC 802 over the Beaufort River and Intracoastal Waterway Bridge consists of two, 12-ft-wide travel lanes; one, 4-ft-wide shoulder; one, 10-ft-wide shoulder that also incorporates a bicycle lane; and a 5-ft-wide pedestrian walkway. The existing McTeer Bridge was re-stripped for one way traffic and dedicated bicycle lanes. The completed bridge, which officially opened in November 2011, provides improved multi-modal access along the SC 802 corridor with protected pedestrian sidewalks and bicycle lanes across the bridge for the enjoyment of the citizens and visitors of Beaufort County, S.C. 

Edward H. Stehmeyer III is a civil engineer with Collins Engineers Inc. in Charleston, S.C.



## DELIVERING SUSTAINABLE SOLUTIONS

**After water, concrete is one of the most sustainable and widely used materials in the world.**

Fly ash plays an important role in increasing the sustainability of concrete. Headwaters Resources is the nation's leader in supplying quality fly ash. We can help you discover how to improve the performance of your concrete while simultaneously improving its environmental profile.

**Visit [www.flyash.com](http://www.flyash.com)** for answers to the most common questions about fly ash. You can also contact your expert Headwaters Resources technical support representative for advice on your specific sustainability opportunities.

[www.flyash.com](http://www.flyash.com)

# What Certification Program are you betting on?



**Certification** is more than inspections, paperwork, and checklists! It must be an integrated and ongoing part of the industry's

**Body of Knowledge!** PCI is the technical institute for the precast concrete structures industry and as such, PCI Certification is an integrated and ongoing part of the industry's body of knowledge.

**Specify PCI Certification**  
and hold the winning hand.



Precast/Prestressed Concrete Institute  
200 West Adams Street | Suite 2100 | Chicago, IL 60606-5230  
Phone: 312-786-0300 | Fax: 312-621-1114 | [www.pci.org](http://www.pci.org)

**Bridges** for **LIFE**<sup>TM</sup>

To learn more, visit [www.pci.org/certification](http://www.pci.org/certification) or contact  
Dean Frank, P.E., PCI director of quality programs,  
at [dfrank@pci.org](mailto:dfrank@pci.org) or (312) 583-6770.

## PROJECT

# I-85 Yadkin River Veterans Memorial Bridges

New dual highway bridges improve safety, accessibility

by Mark Robbins, STV / Ralph Whitehead Associates



To provide serviceability, the bridge utilizes continuous-for-live-load design and detailing for the prestressed concrete girder spans. Photo: Lane Construction Company.

On March 22, 2013, the North Carolina Department of Transportation (NCDOT) opened the southbound I-85 Yadkin River Veterans Memorial Bridge to traffic, completing the major dual highway bridge crossings located between Charlotte and Greensboro, N.C. These bridges and their improved horizontal alignment replaced one of the most dangerous bridge crossings in North Carolina.

The previous I-85 bridges were built in the 1950s and had become one of the most notorious bridge crossings in North Carolina. In addition to being narrow and unsafe, the condition of the existing bridges had become severely

deteriorated. Designed to carry 10,000 vehicles per day, the bridges were subjected to 80,000 vehicles per day including heavy tractor-trailer traffic. The implementation of a cost-effective replacement solution was a dire need.

### Historic, Challenging Site

The Yadkin River is one of the largest rivers in North Carolina. The site of the I-85 Yadkin River Veterans Memorial Bridges is located where historical crossings have occurred and played key roles in the Revolutionary and Civil Wars. This location has been developed to include a Duke Energy power plant and related railroad access on the southern bank; and the Norfolk Southern Railroad

mainline, with a railroad bridge crossing the Yadkin River, and the Spencer Rail Yard on the northern bank. This location is also in the tail water of the High Rock Lake Reservoir and includes extensive wetlands on each side of the river. The site includes approximately 1500 ft of wetland crossing, 700 ft of water crossing, and an upland area adjacent to the railroad tracks. These features combine to severely limit access to the bridge site from the north, west, and east, and impose minor restrictions from the south.

In addition to the owner, motorists, and local citizens, the proposed project involved stakeholders from the Army

## profile

**I-85 YADKIN RIVER VETERANS MEMORIAL BRIDGES / CHARLOTTE AND GREENSBORO, N.C.**

**BRIDGE DESIGN ENGINEER:** STV / Ralph Whitehead Associates, Charlotte, N.C.

**PRIME CONTRACTOR:** Flatiron-Lane Joint Venture, Salisbury, N.C.

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

Corps of Engineers, Division of Water Quality; Duke Energy; Norfolk Southern Railroad; North Carolina Railroad; and Federal Energy Regulatory Commission.

The project solution needed to address safety and stakeholder requirements, limit environmental impacts, and be delivered quickly. The NCDOT selected the design-build best value method to provide that solution.

## New Design Increases Safety

For increased highway capacity and safety, the new roadway utilizes a single, long, super-elevated, horizontal curve with a 17,000 ft radius to eliminate the series of tangents and horizontal curves that characterized the previous conditions. The number of lanes was increased from four to eight and the inside and outside shoulder widths widened to 12 ft. The inside shoulder is designed and constructed to be a future traffic lane.

The clear roadway of the dual bridges is 72 ft with a length of 2914 ft. The vertical grade of the bridge includes a gentle 0.5% grade for a majority of the bridge length and transition to just over 2% to achieve the 23 ft vertical clearance over the railroad tracks. This vertical profile results in pier heights ranging from 25 to 50 ft. The span over the railroad mainline accommodates the two existing tracks and three future tracks. The future tracks are expected to carry a combination of freight and high speed passenger service.

A study of the 245-ft-long railroad span included alternatives of prestressed concrete girders; cast-in-place, post-tensioned concrete boxes; and steel plate girders. This study also factored in the four bridges on the project, which included another single, 800-ft-long Yadkin River crossing on U.S. 29, in selecting the approach spans for the I-85 crossing of the Yadkin River.

From this study, the design-build team selected 77-in.-deep, precast concrete for economical fabrication (PCEF) bulb-tee girders for all spans on the project, except the railroad span. The typical span length is 140 ft, which accommodates the horizontal curvature.

## Design

The bridge superstructures for the I-85 Yadkin River Veterans Memorial Bridges consist of a cast-in-place concrete deck on 20 prestressed concrete girder spans and one steel plate girder span for each of the dual bridges. The skews of the intersecting features vary along the length of the bridge such that trapezoidal spans are incorporated in the concrete section to adjust the skew to meet the railroad alignment.

**To provide serviceability, the bridge utilizes continuous-for-live-load design and detailing for the prestressed concrete girder spans.**

To provide serviceability, the bridge utilizes continuous-for-live-load design and detailing for the prestressed concrete girder spans. The continuous units were limited to two spans to minimize the size of the bridge joints and their initial cost, and to simplify their future maintenance. The top reinforcing mat in the deck is epoxy coated.

Seven girder lines are used for each span resulting in a maximum girder spacing of 11 ft 11 in. Concrete compressive strengths up to 8 ksi were used for the prestressed concrete girders. Galvanized steel intermediate cross frames were used as diaphragms between the concrete girders.



The 2500-ft-long work trestle. Photo: STV.

Elastomeric bearings are used for the prestressed concrete spans.

Another significant superstructure element is the structure drainage system, which directs deck drainage to a treatment basin prior to discharge into the river. Given the 72-ft-wide bridge deck and the prohibition of discharging into the river or wetland, the deck drainage system extends 2300 ft along the side of each bridge.



Girder delivery at the southern end of the bridges. Photo: Flatiron.

A fiberglass-reinforced plastic pipe was evaluated for the project because its thermal expansion properties are approximately 1/6<sup>th</sup> that of polyvinyl chloride (PVC) pipe and is very close to the thermal coefficient of concrete. This minimized issues with differential thermal movements. The pipe, while slightly more expensive than PVC, was used because of its thermal characteristics, flexibility of installation, and lighter weight.

The substructure of the bridge consists of cast-in-place concrete, post and

## NORTH CAROLINA DEPARTMENT OF TRANSPORTATION, OWNER

**OTHER CONSULTANTS:** HDR of the Carolinas, Raleigh, N.C. and Froeling & Robertson, Charlotte, N.C.

**BRIDGE DESCRIPTION:** Dual, 2900-ft-long, 21-span structures utilizing 77-in.-deep, precast concrete for economical fabrication (PCEF), bulb-tee prestressed concrete girders up to 140 ft long made continuous for live-load

**STRUCTURAL COMPONENTS:** 280 PCEF-77 bulb-tee girders; 9-in.-thick, cast-in-place concrete deck; and cast-in-place concrete pier caps, columns, and drilled shafts



Erection of the southbound bridge, which is closely located next to the northbound bridge with the trestle between them. Photo: STV.



North end of the work trestle. Photo: STV.



Northbound bridge opened early to improve safety. Photo: STV.

beam style interior piers. The typical pier caps are 5 ft 6 in. deep and 5 ft 0 in. wide and the columns are 48 or 54 in. in diameter. The foundation is a combination of drilled shafts for the 17 piers in the wetland/water regions and pile footings for the three piers in the upland areas. The bridges include 140 drilled shafts with diameters of 54 and 60 in. and depths up to 80 ft.

### Construction Logistics

The size of the bridges, restricted access, desire for early opening to improve safety in the corridor, and numerous stakeholders presented significant challenges to delivery. Extensive coordination and cooperation with the owner was used to work through the various stakeholder requirements to facilitate design and construction.

The solution for the access to construction was to widen the proposed median such that a construction trestle could be constructed between the dual structures. This approach is generally considered counter-intuitive as typically the approach to minimizing environmental impacts is to reduce the footprint of the project. However, based on a review, it was determined that environmental impacts could be minimized by using a single trestle rather than two work trestles outside each bridge as originally anticipated.

Since the railroad mainline tracks and close proximity to the Spencer Yard and

other site conditions prevented access from the west, north, and east, the temporary trestle was installed from the southern end of the dual bridges. This meant that construction occurred across the wetlands, the river, and to the upland area south of the mainline tracks. This required almost 2500 linear feet of work trestle and created a single access point for all construction south of the railroad track. The contractor implemented and scheduled operations utilizing multiple working shifts as necessary to complete the construction with this limited access.

The first priority of the project was to complete the northbound bridge such that both directions of the existing I-85 traffic could be shifted to the new northbound bridge. This provided significant early safety enhancement to the public as it facilitated early use of the improved horizontal alignment, increased shoulder offsets, and eliminated the reoccurrence of structural maintenance issues on the almost 60-year-old existing I-85 steel beam bridges. Traffic was shifted to the new northbound bridge in May 2012, which was less than two years from the start of construction. Construction of the I-85 southbound bridge and all I-85 widening was completed by May 2013. ▲

Mark Robbins is a vice-president with STV / Ralph Whitehead Associates in Charlotte, N.C.

*Congratulations to the...*

## 2013 ASBI Bridge Award of Excellence — Winners



South Norfolk Jordan Bridge, Virginia

The Charles W. Cullen Bridge Over the Indian River Inlet, Delaware

Veterans Memorial Bridge Replacement, Maine

Miami Intermodal Center – Earlington Heights Connector, Florida

New Cross-Border Combined Bridge Over the Danube River, Romania

Foothills Parkway Bridge Two, Tennessee

# Promoting Segmental Bridge Construction

in the United States, Canada and Mexico

*Remember these dates...*



### April 14-15

2014 Grouting Certification

**T R A I N I N G**

J.J. Pickle Research Campus

University of Texas, Austin



### October 27-28

2014 Annual ASBI

**C O N V E N T I O N**

Hartford Marriott Downtown and

Connecticut Convention Center

For Membership Information or For Further Details, Visit [www.asbi-assoc.org](http://www.asbi-assoc.org)

## Epoxy-Coated Reinforcing Steel

# **COST-EFFECTIVE CORROSION PROTECTION**



Follow us on

Register and Download Free Reports [www.epoxyinterestgroup.org](http://www.epoxyinterestgroup.org)



Celebrate **40 YEARS**  
EPOXY-COATED REINFORCING STEEL



*A Better Product Using 40 Years of Improved Manufacturing and Coating Technologies.*

## PROJECT

# Bridge Replacement: Pecos Street over I-70

Accelerated bridge construction techniques significantly reduce impacts to the traveling public

by Tamara Hunter-Maurer, Colorado Department of Transportation, and Tom Melton, Wilson & Company

The Colorado Department of Transportation (CDOT) bridge department made the determination to replace the Pecos Street Bridge over I-70 because it was structurally deficient and rated poor. The structure spans six lanes on I-70, carries 130,000 vehicles per day, and is located less than a mile away from the heavily traveled I-70/I-25 interchange. For these reasons, it became readily apparent that minimizing disruption to traffic during construction would be a critical element in planning, designing, and constructing the replacement bridge.

CDOT management and the Colorado Bridge Enterprise (CBE) made the

decision that this replacement project was an excellent candidate for applying accelerated bridge construction (ABC) techniques in an effort to significantly reduce impacts to the traveling public. During preliminary design, an ABC evaluation was conducted that confirmed this decision. CBE provided most of the project funding.

This project was slated initially to be only a bridge replacement project, but after site visits, it was determined that there were traffic operation and geometric deficiencies that warranted improvements. The traffic study evaluated 15 alternatives and showed that the best solution was to

replace the two traffic signals at each ramp intersection with two modern roundabouts.

## Design Considerations

Aligned in a north-south direction, Pecos Street marks a dividing line between an industrial area to the east, and the Sunnyside and Chaffee Park neighborhoods to the west. Small communities of local retailers on the fringe of the interchange provide services and goods contributing to the vitality of the area. It was determined during the design process this was an area of environmental justice, which meant any taking of land or right of way purchases for roadway

Rendering of new Pecos Street Bridge over I-70 facing east. Figure: Prepared by Digital Adrenalin for Colorado Department of Transportation.



## profile

**PECOS STREET OVER I-70 / DENVER, COLORADO**

**BRIDGE DESIGN ENGINEER:** Wilson & Company, Denver, Colo.

**GENERAL CONTRACTOR:** Kiewit Infrastructure Group, Littleton, Colo.

**POST-TENSIONING CONTRACTOR:** VSL, Denver, Colo.

improvements would create overall consequences to the community and should be minimized as much as possible.

Replacing the signalized intersections with two-lane roundabouts required only four lanes across the structure. This resulted in a 63-ft-wide deck at the narrowest section in the middle of the bridge. However, the deck flares at the ends of the bridge to accommodate the roundabouts increasing the deck width to 130 ft at the south abutment and 80 ft at the north abutment.

Because there are a number of pedestrians, including those with disabilities, and bicyclists regularly crossing I-70 on the old bridge, it was decided early in the design process to remove the sidewalks from the Pecos Street bridge and provide a separate pedestrian bridge. Further analysis showed construction of a wider street bridge structure to accommodate the pedestrian movement was comparable to the cost of a separate pedestrian structure.

To meet an aggressive 20-month schedule for design and construction set by the CBE funding requirements, CDOT used an innovative project delivery method called Construction Manager General Contracting (CMGC). The contractor was selected and started working on the design with CDOT and the bridge engineer in January 2012. The design was completed in November. The contractor brought ABC experts to the team from recently completed projects utilizing self-propelled modular transporters (SPMTs) in Utah.

To minimize right-of-way impacts, both roundabout footprints encroached on the new roadway bridge, which created an opportunity for the project team to satisfy several project constraints. With the contractor's participation, the



Overview of the bridge staging area (BSA) for the new Pecos Street over I-70 bridge. Photo: 360Media.

structure type, ABC technique, and bridge footprint were finalized. Seven different structure types were initially considered including steel girders, and precast and cast-in-place concrete. The cast-in-place, post-tensioned concrete box girder bridge was selected because it best satisfied the evaluation factors of construction costs, bridge move costs, procurement schedule, structure depth, and aesthetics.

### Superstructure

The superstructure has a span length of 156 ft and consists of three cells with four webs. The two internal webs are straight with a thickness of 12 in. whereas the two external webs are curved in plan with a thickness of 15 in. Web spacing varies from 16 to 23.5 ft. The superstructure is longitudinally post-tensioned internally in the webs and externally in the boxes. The overall depth of the superstructure varies from 76 to 84 in. The transversely post-tensioned deck has a thickness of 9 to 15 in. The bottom slab has a thickness of 6 to 8.5 in. The nonprestressed reinforcement is epoxy coated.

The project team worked closely when selecting the ABC roll-in technique and the internal support system necessary to lift the bridge. Two transverse lifting diaphragms were placed 15 ft from the abutments, and were permanently designed into the bridge

for lifting during transportation. Three-dimensional finite element software was used to design the bridge for all load conditions including loads induced into the bridge during the move.

### Construction

The bridge abutments were designed to be constructed underneath the existing bridge in front of the existing abutments, prior to bridge removal. Thus, the new abutments and superstructure were constructed concurrently, cutting the construction time from 15 months down to seven months—a critical component that allowed the substantial completion date to be achieved.

The superstructure was constructed about 800 ft away from the final bridge location on an abandoned street in the bridge staging area (BSA) in the southeast quadrant of the interchange. In a similar fashion to other ABC roll-in projects, building the bridge in a BSA

**Building the bridge away from traffic provided improved worker safety, construction access, and construction quality.**

## COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

**BRIDGE DESCRIPTION:** A 156-ft-long, single span, cast-in-place, post-tensioned concrete box girder bridge with a variable depth and a transverse post-tensioned deck. The deck overhang span varied from 8.5 to 15.5 ft. Bridge webs were post-tensioned internally and externally, exterior webs were curved, and web spacing varied from 16 to 23.5 ft



The edge of the deck and exterior webs are curved to accommodate the roundabouts at each end.  
Photo: Colorado Department of Transportation.



Steel street plates were used to protect travel path surfaces and prevent tires from digging into fill material. Photo: Wilson & Company.



Climbing jacks at final height above ground.  
Photo: Wilson & Company.



Self-propelled modular transporter equipment installed and ready to move the bridge. Photo: Wilson & Company.



Spectators view from the public viewing area during the bridge move weekend. Photo: Wilson & Company.

away from traffic provided improved worker safety, construction access, and construction quality.

### Moving the Bridge

The project team collaborated on designing the temporary and permanent construction elements required to move the bridge. Major features of the bridge move included:

- jacking the bridge 17 ft above the ground using climbing jacks,
- placing SPMT supports under the lifting diaphragms,
- transporting the bridge along a travel path, and
- setting the bridge on adjustable bearing devices.

The project team conducted 13 meetings and spent hundreds of hours refining the design of the moving equipment and the lifting diaphragms resulting in a design compatible for both. The travel path design required significant coordination time to ensure that:

- the 3% maximum grade for the equipment stability was not exceeded,
- twisting of the bridge was not induced, and
- the vertical stroke on the SPMT equipment worked both to lift the bridge off the climbing jacks, as well as to set the bridge in the final resting place on the new abutments.

On Friday evening, July 19, 2013, at 10:30 p.m., I-70 was closed and then re-opened 50 hours later on Monday morning at 12:30 a.m. During this

weekend closure, the existing bridge was demolished and removed, the bridge travel path was constructed using metal plates and fill material, the bridge moved, and the travel path removed. The bridge did not develop any new cracks as a result of the move.

### Public Participation

CDOT set up a public viewing area near the travel path to allow spectators to witness this unprecedented construction method for Colorado. Throughout the weekend, there were over a 1000 spectators that observed and cheered on the construction team as the bridge slowly moved into final position.

One of the great successes for this project is not simply that CDOT tried a fairly new innovative construction method, but that it almost completely eliminated impact on the I-70 traveling public. In addition, CDOT worked closely with the local businesses on either end of the bridge to make sure people had access to their services throughout construction.

With the Pecos Street over I-70 Bridge in place, the roundabout construction was finalized and Pecos Street reopened Labor Day weekend, September 1, 2013. 

Tamara Hunter-Maurer is a project manager with the Colorado Department of Transportation in Denver, Colo., and Tom Melton is a bridge designer with Wilson & Company in Denver, Colo.

# Precast Provides the Resiliency Needed to Withstand a Cat 5 Hurricane

After Hurricane Katrina destroyed the U.S. 90 Bridge over Biloxi Bay, the Mississippi Department of Transportation knew the new 1.6 mile bridge would have to be able to withstand a Category 5 hurricane. It also had to include a 250-foot navigation span, require minimal maintenance and be constructed quickly. Precast concrete's inherent strength, durability, and speed made it the obvious choice.



Discover **High Performance** Precast  
Versatile | Efficient | Resilient

For more information  
and free continuing  
education, visit

[www.pci.org/hpprecast](http://www.pci.org/hpprecast)



# Reconstruction of Downer Place Bridges

by Robert Davies, HR Green Inc.



*New precast, prestressed concrete deck beam bridge over the East Branch Bridge, as constructed in 2012.  
All photos: HR Green Inc.*

**T**wo bridges were replaced recently over the east and west branches of the Fox River in downtown Aurora, Ill., the state's second largest city. The original bridges were three-span, filled spandrel arches constructed in 1909 of cast-in-place concrete. The bridges connect historic Stolp Island to the rest of Aurora, and were listed on the National Register of Historic Places.

Historic preservation criteria mandated that the completed appearance be similar to

that of the original construction including arches, concrete railing, and lighting (as indicated on photographs from archives). To replicate a historic appearance with modern techniques, three spans of precast, prestressed concrete deck beams, precast concrete fascias in the shape of the original arches, precast concrete outlooks at each pier (also in the shape of the original outlooks), and precast concrete railings were specified. Period lighting (again based on

archive photographs) was also installed. The original piers and abutments were removed to the waterline and reconstructed with cast-in-place concrete to the bearing elevations for the precast concrete elements.

Design was complicated by extensive utility conflicts, lack of drawings for the existing bridges, and the abutments being integral with historic building foundations dating to the 1840s. The project was let for bid in September of 2011 by the Illinois Department of Transportation. Seven bids ranging from \$6.8 million to \$8.5 million were received. The contract was awarded on November 18, 2011. The city of Aurora held a grand re-opening and ribbon cutting ceremony for the new bridges on December 12, 2012.

While the schedule for this high-profile project caused initial concerns among city officials and business owners, the use of precast concrete architectural and structural elements and dry weather, allowed the contractor to meet an aggressive, one-year construction schedule. 

*Robert Davies is a senior professional with HR Green Inc. in McHenry, Ill.*

*West Branch Bridge, constructed in 2012.*



# I-5 Skagit River Bridge Collapse and Rapid Replacement

by Tom Baker, Dr. Bijan Khaleghi, Todd Harrison, Patrick Fuller, and Rich Zeldenrust, Washington State Department of Transportation

On May 23, 2013, the evening commute was just ending along a four-lane stretch of the Interstate 5 (I-5) corridor between the Canadian border and Seattle. At roughly 7 p.m., a semitruck heading south and carrying a permitted oversized-load struck the first portal and several subsequent sway members along the steel truss section of the I-5 Skagit River Bridge. The northern truss span of the bridge collapsed into the Skagit River. While the semi-truck made it across, several vehicles didn't and the occupants had to be rescued. Fortunately, no one was killed in the collapse.

The Washington State Patrol, the Washington State Department of Transportation (WSDOT), and local agencies responded immediately, setting up and manning detour routes both east and west of the bridge.

WSDOT immediately responded with bridge engineers to assess the damage and begin plans for both emergency and permanent repairs, while communication staff responded to the media, and sent out updates and freight alerts region-wide. Traffic engineers worked through the night to refine the detour routes for the roughly 71,000 vehicles that were detoured through the city streets of Burlington and Mount Vernon.

Within 24 hours, a contractor was hired under an emergency contract to remove the collapsed span, and began working with WSDOT engineers to install a temporary span to get the interstate back open. As the work was being done to temporarily restore I-5 traffic, WSDOT engineers began assembling contract documents for a permanent span repair.

## Bridge Type Selection

Hours after the collapse, discussions were underway at WSDOT about how best to replace the collapsed span,

and how to restore traffic as quickly as possible. Time requirements, vertical clearance requirements, and superstructure dead load limitations quickly became the primary guiding factors in designing the span replacement.

Minimizing traffic disruptions dictated the installation of temporary, side-by-side, dual-lane, modular truss bridge spans, which were subsequently replaced with the permanent span. For navigational purposes, vertical clearance to the river below had to be equal to or greater than that provided by the original truss span. And, importantly, to minimize any additional seismic inertial loads to the existing bridge substructure, the dead load of the replacement span could not exceed the dead load of the original truss span by more than 5%.

The design-build method (D-B) was chosen for the permanent span replacement with the goal of rapid construction. Three options were investigated: a steel through-truss (a near duplicate of the original span), a steel plate girder span with a concrete deck, and a prestressed concrete girder span with a concrete deck. The steel through-truss, though light in weight and aesthetically consistent with the original bridge, was thought to be too time-consuming to fabricate and erect. The project was advertised for proposal with the assumption that the most-likely structure types for proposal were going to be the steel or concrete girder options.

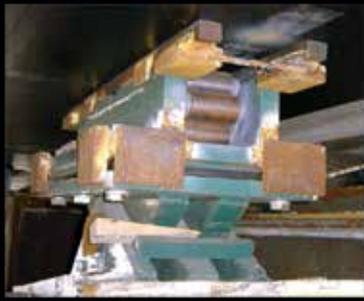
Four D-B teams submitted proposals for the permanent span replacement. Two proposals included the steel girder option and two proposals included the prestressed concrete girder option. WSDOT selected the best-value proposal, which utilized a prestressed lightweight concrete girder deck bulb-tee replacement span.



Lightweight concrete deck bulb-tee beams with a lightweight overlay erected on steel piling and bents. Photo: Washington State Department of Transportation.

# MOVE THE HEAVYWEIGHTS!

Move Bridges Efficiently & Safely



**HILMAN  
ROLLERS**

WWW.HILMANROLLERS.COM

12 Timber Lane • Marlboro NJ 07746 • USA

tel: (732) 462-6277 • fax: (732) 462-6355 • e-mail: sales@hilmanrollers.com

Lightweight concrete was specified for the girders, diaphragms, and barriers to stay within the stipulated span dead load limitations. The chosen concrete girder proposal offered competitive initial costs, low overall life-cycle costs, the shortest girder procurement time, and the minimum closure time required to replace the temporary span with the permanent span.

## Replacement Span Design

The WSDOT plan to reconstruct the I-5 Skagit River Bridge consisted of constructing the permanent replacement span using accelerated bridge construction techniques. The 160-ft-long permanent replacement span, composed of 65-in.-deep deck bulb-tee girders made of lightweight concrete with



Lightweight deck bulb-tee girders in the casting yard. Photo: Washington State Department of Transportation.

a silica fume concrete overlay, was built adjacent to the bridge and its temporary spans.

The new permanent bridge was analyzed and designed using the current *AASHTO LRFD Bridge Design Specifications* and the *WSDOT Bridge Design Manual*. The WSDOT Bridge and Structures Office provided over-the-shoulder reviews of the bridge engineer's design, shop drawings, and construction submittals.

In order to limit the weight of the superstructure, the girder spacing of 7 ft 3 in. was considered to keep the replacement structure as light as possible. Using 7 ft 3 in. girder spacing eliminated one line of girders to reduce the total superstructure weight. The total weight of the new superstructure including the lightweight concrete traffic barriers and concrete overlay was 915 tons, within the limit required by the contract.

Differential camber and reflective cracking are the two performance challenges involved with use of deck bulb-tees for long spans. In order to minimize the reflective cracking the superstructure

design required the use of a 1½ in.-thick concrete overlay instead of hot-mix asphalt and the use of high-strength concrete and overlapping bars instead of welded connections.

The differential camber was adjusted using leveling beams prior to casting concrete at the closures. The predicted camber for lightweight deck bulb-tee girders was 6.5 in., and the measured girder cambers at erection were slightly above the predicted camber. The span-to-depth ratio of 29.5 for the new superstructure met the *AASHTO LRFD Bridge Design Specifications* criteria for live-load deflection.

The design compressive strength of lightweight concrete used for the deck bulb-tees was 9.0 ksi, with a compressive strength



Erection of girders with a 500-ton crane on the river dike and a 200-ton crane on the barge. Photo: Washington State Department of Transportation.



Location of replacement span during construction. Rendering: Parsons Brinckerhoff.

of concrete at transfer of prestress of 7.0 ksi. The fresh unit weight of lightweight concrete was 0.122 kip/ft<sup>3</sup>, with the unit weight of the girder of 0.133 kip/ft<sup>3</sup> for design and dead load calculations. A total of forty-eight 0.6-in.-diameter strands were used for design of girders.

Intermediate diaphragms were located at two temporary supports that were 20 ft from the end of girders; the support locations were moved to accommodate the bridge move. Temporary strands in the top flange of the girders were provided to compensate stresses due to negative moment at the temporary supports.

## Replacement Span Construction

The contractor received notice to proceed on June 19, 27 days after the collapse and the design phase started immediately. The design was completed on July 9, which was 47 days after the collapse. The project's scope of work included construction of the new span over the river, and adjacent to the bridge's two temporary spans, then removal of the temporary spans and placement of the single, permanent span.

The permanent superstructure was constructed on steel piling and bents, just downstream of the temporary spans. The girders were set using a 500-ton crane on the river's dike and a 200-ton crane on a barge system. The crane picks were quite detailed. Each pick required 19 specific moves, including passing the end of the girder from the dike crane to the barge crane, tucking the girder under the boom of the barge crane—while re-ballasting the barge system—and finally re-ballasting the barge as the girder was placed on the temporary bents.



Deck closure reinforcement. Photo: Washington State Department of Transportation.

Separate rows of piling and bents were built to support a rail system that would be used to slide the temporary spans out, and slide the new span into place.

To complete the bridge, the girders were tied together with end diaphragms and closure concrete placements between the girders. This was followed by casting the traffic barrier and a 1.5-in.-thick silica fume deck overlay. Separate, intermediate diaphragms acting as jacking beams were also installed using reinforced cast-in-place concrete.

A vertical and horizontal jacking system was concurrently installed using a rail system supported by temporary piling and bents. To complete the installation of the new span, first the temporary spans were lifted off the existing substructure and slid off onto the temporary bents upstream of the bridge. The new span was moved upstream in a similar fashion, with the exception that it needed to be shifted ½ in. longitudinally to fit into place.

The overall construction started on July 12 and the new span was opened to traffic on September 15. It took just under 19 hours to swap the spans and open the freeway to traffic. To finish up the work, the temporary spans were disassembled onto the barge system and all of the piling was removed from the river.

## Future Activities

What's next for this bridge? Successful as the replacement of the collapsed bridge was (the number of closed days totaled only 28), there is little rest for the designers and contractors. With the permanent replacement span in place, attention turns to the remaining sway-frame truss sections and their vertical clearances. While truckers are responsible for their over-height loads, states are prudent to examine over-height hits and apply mitigation if possible. In this case, that means removing and replacing the lowest height elements of the trusses, increasing the vertical clearance across the two outside lanes, and helping to extend the already long-life of the I-5 Skagit River Bridge. **A**

*Tom Baker is a state bridge engineer, Dr. Bijan Khaleghi is a state bridge design engineer, and Rich Zeldenrust is a design unit manager in the bridge and structures office of the Washington State Department of Transportation (WSDOT) in Olympia, Wash. Todd Harrison is assistant region administrator for the Mt. Baker Area of WSDOT in Mt. Vernon, Wash. Patrick Fuller is a project engineer for the northwest region of WSDOT in Bellingham, Wash.*

*Team members for the I-5 Skagit River Bridge included Parsons Brinckerhoff, bridge design engineer, Tampa, Fla.; Max J. Kuney Company, prime contractor, Spokane, Wash.; and Concrete Technology, precaster, Tacoma, Wash.*

## EDITOR'S NOTE

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

# Another Bridge Life-Cycle Cost Analysis Tool for MAP-21

by Nathaniel Coley, Federal Highway Administration, and M. Myint Lwin, retired from Federal Highway Administration



This article is a follow-up to the articles titled “Map-21 and Bridge Life-Cycle Cost Analysis” and “Using Bridge Life-Cycle Cost Analysis Tools for MAP-21” published in the Summer 2013 and Fall 2013 issues of *ASPIRE*,<sup>TM</sup> respectively. This article describes the National Bridge Investment Analysis System (NBIAS) for network level life-cycle analysis for making program investments to help meet certain performance targets, or for meeting MAP-21 requirements. Examples on the use of NBIAS are given in this article.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) builds on the network management practices in its requirements for Asset Management Plans and Transportation Performance Management Plans. It provides the basis for examining a mixture of investment strategies to make progress toward achieving state-specified performance targets. MAP-21 requires that the deck area on national highway system (NHS) bridges classified as structurally deficient in the state not exceed 10% of the total deck area of all NHS bridges in the state.

## National Bridge Investment Analysis System

To analyze network level strategies, states can use the NBIAS software. It uses state collected National Bridge Inventory (NBI) data to deteriorate all the bridges on a state’s network using algorithms for each element on the bridge. It then assigns financial resources to cost-beneficial corrective actions. The software includes cost tables and adjustment factors for different states and climate zones.

Scott McClure, chief of the New Mexico Department of Transportation’s Research Bureau says, “It is really a quite impressive application and seems to be a very powerful analytical tool.” The analyst simply uploads their state’s data and enters information such as annual budgets, performance targets, and benefit-cost ratio (BCR). The BCR identifies the threshold for an acceptable investment. Data can be aggregated to various levels, such as county or state.

The NBIAS output reflects a program of investments, covering a time horizon, that could support progress in achieving performance targets or meeting MAP-21 requirements. Users can generate reports describing over

200 performance measures such as “percent of deficient bridges by deck area” or identify the additional costs of postponed investments resulting from various budget scenarios. A risk-based plan or program reflecting various budgeting scenarios can be explored using NBIAS. Annual recommended actions for each bridge on the network can also be displayed in the results.

## Examples

Figure 1 depicts an example analysis of the impact of different budgets that a state may face in moving its bridge network to the MAP-21 minimum threshold of no more than 10% of the total deck area of bridges in the state located on structurally deficient bridges. It presents four annual funding scenarios, an unconstrained/unlimited budget, a \$202-million budget including 3% annual increase, a \$305-million budget, and a \$240-million budget with an influx of \$600 million in year one, possibly from a one-time revenue measure. NBIAS identifies the most efficient types of investments under each budget scenario and assigns financial resources to those investments. Under the unconstrained/unlimited budget scenario, the state can achieve the target in the first year.

Under the \$202-million budget including 3% annual increase, which represents current trends for this example state, the target would not be met within the timeframe of the analysis. The \$305-million budget scenario and the \$240-million budget with an influx of \$600 million in year one both trend toward the target similarly. With this information, a state bridge engineer would be strategically equipped to advise senior management on how the budgets will affect the state bridge network.

Figure 2 identifies the maintenance needs from various annual budgets. The four budgets represented in the graph are \$27 million, \$32 million, \$35 million, and \$50 million. The costs of all maintenance needs for all network bridges are depicted on the vertical axis. We can derive from the graph that a \$15 million reduction from \$50 million to \$35 million in funding for bridges would cost the state approximately \$163 million in additional maintenance needs over the 10-year analysis period. “The ability to identify the increased long-term costs due to budget cuts makes NBIAS a powerful tool for assessing our programs as well as communicating to senior management and law makers,” says Scott A. Hill, Connecticut State Manager of Bridges and Facilities.

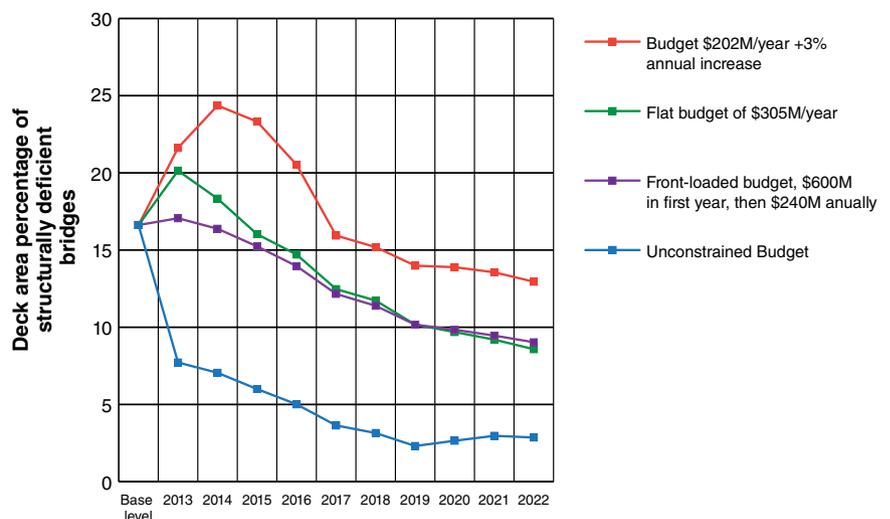


Figure 1: Example of a risk-based plan from the National Bridge Investment Analysis System software. All figures: Federal Highway Administration.

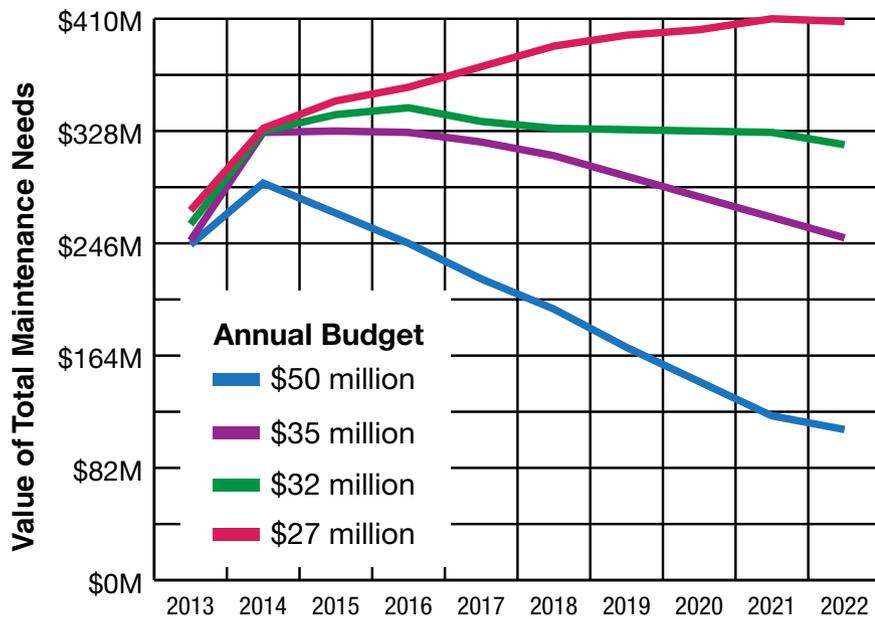


Figure 2: Example of impacts of annual budgets on the maintenance needs from National Bridge Investment Analysis System software.

## Closing Remarks

NBIAS is most effective for exploring the network outcomes of various funding and investment scenarios and developing a risk-based plan. Output from a bridge management system along with output from NBIAS can be used as an analysis of efficient bridge investments. The results of an NBIAS analysis can also provide insight on which project level investments best support progress toward the state targets in meeting the MAP-21 requirement that the deck area on NHS bridges classified as structurally deficient not exceed 10% of the total deck area.

Please visit FHWA's economic resources internet web page at <http://www.fhwa.dot.gov/infrastructure/asstgmt/invest.cfm> or contact Nathaniel Coley at 202-366-2171 or [ncoley@dot.gov](mailto:ncoley@dot.gov) to request additional information about the free NBIAS software and workshop. 



Expanded Shale Clay and Slate Institute

## Expanded Shale, Clay and Slate Institute

The Expanded Shale, Clay and Slate Institute (ESCSI) is the international trade association for manufacturers of expanded shale, clay, and slate (ESCS) aggregates produced using a rotary kiln.

This issue of ASPIRE includes two articles that mention the use of lightweight aggregate in bridges.

In the focus article on Beam, Longest and Neff (BLN), bridge department manager Michael L. McCool, Jr. mentions the successful use of both lightweight concrete for increasing beam lengths and internal curing using lightweight aggregate to reduce shrinkage cracking in bridge decks.

In the ABC article, WSDOT reports on the rapid replacement of the I-5 truss span over the Skagit River. Lightweight concrete was used for the prestressed concrete deck girders, diaphragms and barriers which allowed the designers to replace the truss span with a concrete solution of approximately the same weight, eliminating the need to analyze or modify the substructure units. The 162 ft long, 65 in. deep deck bulb tee girders were fabricated using sand lightweight concrete with a design compressive strength of 9 ksi and a concrete density of 122 pcf. This bridge is an excellent example of using lightweight concrete to address design challenges and provide an economical, rapid and durable concrete bridge solution.



For more information about lightweight concrete, internal curing and ESCS aggregate, visit [www.ESCSI.org](http://www.ESCSI.org).



# MAINE

## New girder shapes, delivery methods spur new concrete techniques

by Wayne Frankenhauser Jr. and Michael Wight, Maine Department of Transportation



*The 1610-ft-long Veterans Memorial Bridge, at a cost of \$44.2 million, is the largest design-build project completed in Maine. Photo: Kimberly Brooks, T.Y. Lin.*

**C**oncrete bridges have a long history in Maine, and concrete bridges will continue to be built in the future because of new girder shapes, delivery methods, concrete technology, and erection methods that are being introduced. In many cases, these innovations make a major difference in cost, speed, or longevity.

Overall, the Maine Department of Transportation (MaineDOT) is responsible for 3700 bridges and minor spans, with total responsibility for about 2000 bridges and 800 minor spans. The rest have shared responsibility, including about 170 bridges overseen by the Maine Turnpike Authority. Approximately 45% of state-owned bridges are made with concrete.

Historically, there have been a tremendous number of concrete structures built in Maine. Concrete slab and tee beam bridges dominated construction until World War II, and concrete bridges continue to be a major design option. A key design consideration in Maine is the number of salt-water and fresh-water crossings where the bridge superstructure is very close to the water. Concrete is the material of choice because it performs well in these environments, and does not require costly coating systems.

Another factor when selecting materials for bridges is Maine's climate. There are frequent freezing and thawing cycles in the winter and spring, and the state uses lots of deicing chemicals to keep roads safe. This environment can be extremely harsh on bridges with elements exposed to salt spray from passing vehicles.

### Extending Service Life

These factors inhibit Maine's goal of achieving a 100-year service life for its bridges, which is a high priority for MaineDOT. Teams often struggle to reach this goal, but are finding more techniques, in both materials and design details, to achieve it. Techniques that are proving

valuable include high-performance concrete with low permeability and the use of corrosion-resistant reinforcement and strand such as epoxy-coated, glass fiber-reinforced polymer, carbon fiber-reinforced polymer, stainless steel, and dual-coated steel systems. These alternatives do not represent wholesale changes, but offer new approaches to details that can provide significant longevity, durability, and strength.

Strength is critical because it allows longer span lengths which can eliminate piers and joints. Eliminating joints offers a major way to prevent moisture penetration from becoming an issue, and Maine is working on more designs that take this approach.

As span techniques change, Maine is using more prestressed or post-tensioned precast concrete girders, such as box beams and segmental construction. For bridge spans less than 100 ft long, a precast concrete design is typically used, but this length has been increasing as more options are available.

### NEXT, NEBT Benefits

Two innovative shapes helping Maine achieve its goals are the New England bulb-tee (NEBT) and New England extreme tee (NEXT) beams. Developed in conjunction with the Precast/Prestressed Concrete Institute's Northeast regional chapter, these girder shapes have achieved tremendous buy-in from local designers and contractors owing to the added benefits they provide. Their shapes help eliminate steps in the construction process; thereby speeding construction. Maine has become quite familiar with these designs, and they are the shapes most often used for I-beams today. Although the NEXT beams are quite new, Maine has already built about 10 bridges using them and has been very impressed with their performance so far.

The first NEXT-beam bridge built was the New Bridge over the York River on Route 103 in York, Maine, which was designed to be jointless. The seven-span, 510-ft-long structure replaced a 17-span, steel-girder bridge and features 55-ft-long end spans and 80-ft-long center spans, with integral abutments and pile-bent piers. Two options were provided, NEBT or NEXT girders.

The contractor selected the NEXT beam option to meet a variety of goals, including maintaining the existing profile, improving navigational clearance, and avoiding conflicts with existing substructure locations. The design met all the goals and provided 4 in. of additional clearance.

Designers like the NEXT beam because it provides a top flange that can support the cast-in-place deck without an intermediate diaphragm. It also has no closed sections, making inspections easier and providing a location for utilities. The NEXT beam will likely dominate the market in coming years.



*The New Bridge over York River was the first use of the Northeast Extreme Tee (NEXT) beam.*

*Photo: Vanasse Hangen Brustlin Inc.*

### New Delivery Methods

MaineDOT also is embracing new delivery methods, including design-build and construction manager/general contractor (CM/GC) approaches because of the innovations, speed, and cost savings they can generate. The format is chosen depending on the reasons for the project, available funding, and timing.

Design-build methods are being used more often—about eight have been completed in recent years—primarily when speed is of the utmost concern or the project is large and complicated. Those methods offer more opportunities for contractors to use their own



*The Penobscot Narrows Bridge in Waldo and Hancock Counties, a cast-in-place concrete segmental cable-stayed bridge, was created when renovation plans showed needed repairs were too extensive. The distinctive bridge was completed in just 30 months. Photo: Maine Department of Transportation.*

expertise and skill to reduce time and costs for the project. By not being overly prescriptive to the design-build team, some good innovations have resulted. Often, the project has specific challenges and the contractors have created great solutions.

An example is the Penobscot Narrows Bridge in Waldo and Hancock Counties. The design consists of a cast-in-place, concrete segmental, cable-stayed bridge. A design-build system was used because initial plans to renovate the old bridge were scrapped once the extent of deterioration became known. The 2120-ft-long cable-stayed design provided a signature look for the historic area proved to be the most cost effective, and would allow traffic access quickly. It was completed in just 30 months.

One of the largest design-build projects undertaken was the 1610-ft-long Veterans Memorial Bridge, which is used by about 22,000 vehicles per day. The \$44.2-million structure consists of twin post-tensioned, precast concrete, segmental box-girders with cast-in-place concrete piers. The structures, with segments varying from 8 to 11 ft in length, were joined with a cast-in-place concrete closure strip.

By offering the design-build option and alternative technical concepts, the team was able to propose a new alignment that saved significant time and money, and shortening the bridge by 800 ft. This strategy not only saved initial cost and long-term maintenance needs, but it dramatically improved the intersection. These results are why Maine will continue to use design-build options in the future.

## Speed Is Key Focus

Speed of construction has become a key focus, especially when emergencies arise. The emphasis on reducing user costs has led to new techniques that offer dramatic results. The rebuilding of the Bracket Brook Bridge and North Branch Bridge in the Carrabassett Valley in 2011 are prime examples of what can be accomplished. Destroyed by Hurricane Irene, the bridges provided the main access to Sugarloaf

Mountain, a major ski-resort area. Their loss created a 79-mile detour a few months before the ski season began. The project was let on a CM/GC basis, with the goal of having temporary bridges in place within seven days of the August 28 destruction and permanent replacements ready in less than three months. Adjacent precast concrete voided slabs were chosen for Brackett Brook Bridge, while adjacent box beams were selected for the North Branch Bridge. These choices were selected by MaineDOT and the contractor based on input from local suppliers for what products were most available and fastest to deliver and construct.



*The Brackett Brook Bridge and North Branch Bridge (shown here) in the Carrabassett Valley had to be rebuilt quickly following their destruction in 2011 by Hurricane Irene. Completed on a CM/GC basis, different concrete designs were used for each based on materials available for fastest construction. They were reopened in less than three months. Photo: Maine Department of Transportation.*

Although created on an emergency basis, the project became a lesson in constructability and accelerated bridge construction techniques. The bridges have conventional designs, with integral abutments, but the speed of construction was extraordinary. The ability to achieve this pace through close coordination with the contractor proved that having this input early can provide a big benefit.

## Aesthetics More Important

Aesthetics has become more important, primarily for urban areas where bridges are more prominent. Regardless of location, local stakeholders have become more involved in the process, with concerns about appearance,

duration of construction, and other factors.

An example is the Covered Bridge over the Kennebec River in Norridgewock, Maine, which had to be replaced despite being named one of Maine's most significant twentieth-century bridges. A 10-person committee, including local authorities and other state stakeholders, agreed on a new bridge that replicated the historic appearance but provided a 100-year service life and additional clearance over the river.

Designers created a three-span bridge with a cast-in-place, tied-arch center span and precast, prestressed concrete bulb-tee beam approach spans. The tied-arch span contains two parallel 300-ft-long concrete arch ribs with six cast-in-place transverse braces. The arches rise 60 ft above the deck.



*The new design of the Norridgewock Bridge consists of a three-span bridge with a cast-in-place, tied-arch center span and precast, prestressed concrete bulb-tee beam approach spans. Photo: Maine Department of Transportation.*

These examples show ways that MaineDOT is using concrete designs and techniques to reduce costs, provide longer service lives, and speed construction of its bridges of all shapes and sizes. Alternative contracting methods and techniques to extend service life will continue to be employed, especially with new ways to eliminate bridge joints. Maine's goal is to better serve its citizens by taking designs for cast-in-place concrete and precast concrete bridges to the next level. ▲

*Wayne Frankenhauser Jr. is assistant bridge program manager and Michael Wight is an engineer with the Maine Department of Transportation in Augusta, Maine.*

## EDITOR'S NOTE

*For more information about the bridges mentioned in this article, see the following issues of ASPIRE™: New Bridge, Spring 2011; Penobscot Narrows, Winter 2007; Veteran's Memorial, Summer 2012; and Covered Bridge, Fall 2011.*



## Restoring a Vital Link in Rhode Island

by **Bharat Patel, Vanasse Hangen Brustlin Inc.**

On October 24, 2012, the rehabilitated Stillwater Viaduct Bridge, spanning the Woonasquatucket River in Smithfield, R.I., reopened for traffic approximately five weeks ahead of schedule. This important transportation link for in-town traffic and people traveling along the George Washington Highway will help boost local businesses and future economic development, and is a critical investment in Rhode Island's infrastructure.

The 80-year-old Stillwater Viaduct Bridge—at 450 ft long with 11 spans, including huge concrete arches over the water—carries approximately 8700 vehicles daily along Route 116 crossing the Stillwater Reservoir. The existing superstructure, because of its severely deteriorated condition and structural integrity, was replaced as part of Rhode Island's Comprehensive Bridge Improvement Program. The structure was replaced with a bridge of the same width with sidewalks through a \$9.4 million contract. To expedite the process, Rhode Island Department of Transportation (RIDOT) chose to close the bridge to traffic during construction, and used precast concrete components where possible.



Underside view of the rehabilitated Stillwater Viaduct Bridge. Photo: Vanasse Hangen Brustlin Inc.

The replacement of the bridge superstructure is an excellent example of how good planning, local-state cooperation, and efficient construction techniques, result in successful completion of a project under budget and ahead of schedule.

The two-lane bridge is an open spandrel, reinforced concrete, three-ribbed arch spanning 80 ft. The concrete approach spans vary in length and are supported on 10 concrete column bents consisting of three square columns.

In lieu of constructing the bridge in phases over three-years, RIDOT chose to close the bridge to traffic during construction. By using precast concrete elements, the bridge was substantially completed in only seven months.

Due to its classic design and age, the Stillwater Viaduct Bridge is eligible for listing on the National Register of Historic Places for its historical association with the massive bridge building campaign, and for serving as an important local example of an open spandrel arch bridge.

The existing, deteriorating superstructure was replaced with precast concrete stringers, pier caps, floor beams (at the arch span), fascia beams with cantilevered brackets, spandrel beams (at the arch span), and decorative bridge rail with spindles. The bridge deck is 8-in.-thick, cast-in-place concrete with a waterproofing membrane covered by a 3-in.-thick asphalt overlay. The new bridge incorporates all the historical elements of the originally constructed bridge.

The rehabilitated structure increases load capacity and lifespan of the bridge, and reduces the number of expansion joints over the arch span. In addition to making the bridge safer for vehicles, it is now open to pedestrians for the first time in years. Its long-closed and crumbling sidewalks have been restored and are protected from traffic by steel rails.

The new Stillwater Viaduct Bridge improves the daily lives of Rhode Island commuters and the accelerated schedule has been very well received. This rehabilitation project can serve as an example to the industry of how community involvement and innovation can contribute to successful bridge rehabilitation projects. **A**

*Bharat Patel is managing director of transportation engineering with Vanasse Hangen Brustlin Inc. in Providence, R.I.*



Aerial view of Stillwater Viaduct Bridge. Photo: Mark Flannary Photography.

# Rehabilitation of the Jacks Run Concrete Arch Bridge

by Daniel Wills,  
MS Consultants Inc.

The 590-ft-long Jacks Run Bridge connects Bellevue Borough to the Brighton Heights neighborhood on the north side of the city of Pittsburgh. A main route connecting urban residential neighborhoods, the bridge is a vital link for vehicular, mass transit, and pedestrian traffic.

Built in 1924 for Allegheny County, the bridge prominently features a 320-ft-long concrete arch and 14 concrete slab spans. At the time of construction, the bridge was the longest of the county's open spandrel arches.

Due to extensive deterioration and high chloride content, it was determined that the entire deck and the floor beams, jack arches, abutment back walls, and columns adjacent to the expansion joints should be replaced. For the remaining concrete elements, an extensive program of repairing over 6000 ft<sup>2</sup> of spalls and delaminations was required.

To prevent eccentric loading that could potentially damage the arch ribs, the new deck had to be placed in a specific sequence. This required two deck finishing machines starting at the center of a concrete placement heading in opposite directions. The end result was a deck placement sequence that was never more than 20 ft out of symmetry relative to the arch, and with no intermediate construction joints.



Jacks Run Bridge after rehabilitation. Photo: Henry G. Russell Inc.

Because the bridge is historic, the proposed rehabilitation had to improve the historic quality of the bridge by restoring previously replaced elements to more closely match the original bridge. This included the replacement of the existing steel hand railing and modern lighting fixtures with a vertical face concrete parapet and a lighting system that matches the original 1924 lighting. Removable forms were also specified for the deck to maintain the appearance of the structure. Due to the limited access and to span the large distances between floor beams, a lightweight forming system utilizing retractable aluminum beams weighing less than 80 lb was used. This permitted the contractor to dismantle and remove the forming by hand from the under-deck. Also, all exposed surfaces below the deck were recoated with a high-build, latex-modified, cementitious damp-proof coating to provide a uniform appearance and cover the previously applied cementitious coating that was peeling in many places making it spotty and unattractive.

To extend the life of the rehabilitated structure, measures were taken to mitigate corrosion. Galvanized reinforcement was used for the floor beams and columns at the expansion joints. The distance between the floor beams was increased and the sides of the floor beams were sealed with epoxy resin sealer. Also, two different types of galvanic anode corrosion protection systems were installed. For the concrete repair areas, zinc puck shaped anodes were placed around the perimeter of patches to prevent halo corrosion. In the larger elements being replaced, distributed anode rods were used. Both anode systems were designed for 25-year corrosion prevention.

By implementing a thorough program of planning, coordination, and community input, a design was prepared for Allegheny County that will provide many years of additional service. Attention to detail and extra protective measures at the most vulnerable elements will extend the structure's life-span significantly. In addition, all work was performed in a manner sensitive to the historic character of the bridge, and with minimal disruption to the community. ▲

Daniel Wills is a chief bridge engineer with MS Consultants Inc. in Coraopolis, Penn.



Reconstructing a new column during rehabilitation of the Jacks Run Bridge. Photo: MS Consultants Inc.

# Bootstrapping Up

## The New Jersey Turnpike Authority gets its feet wet with its first precast, post-tensioned concrete bridges over coastal waterways

by William Wilson, New Jersey Turnpike Authority

**T**he New Jersey Turnpike Authority (NJTA) is a major toll road agency in the northeast that operates the two largest roadway facilities in New Jersey; the Garden State Parkway and the New Jersey Turnpike. The NJTA's facilities are undergoing an expansive improvement program to better serve a growing population and support increasing traffic to the vibrant coastal resort communities in the region.

This program addresses the aggressive environmental conditions of New Jersey's southern coastal region, where bridges are subjected to salt water spray and repeated deicing salt usage. These conditions have taken their toll on the roadway over its 60-year service life, and bridges over the most exposed waterways warranted replacement. From this program emerged three challenging new bridge projects for which precast, prestressed, post-tensioned concrete girder superstructures were ultimately chosen: the 1230-ft-long Mullica River Bridge, the 900-ft-long Bass River Bridge, and finally the 3834-ft-long Great Egg Harbor Bridge. Prior to these bridges, the NJTA had limited experience with this type of structure. Each project was a step forward for the NJTA in understanding the bridge type and culminating in three state-of-the-art concrete bridges.

### Going in Head First

The NJTA's first two experiences with long-span concrete bridges came in the form of the Mullica and Bass River Bridges.

Precast, prestressed concrete was determined to be the preferred alternative in order to reduce future maintenance concerns that go along with painted steel in an aggressive environment. Given the cost and complexity of the pier construction, along with a limited timeframe for in-water construction due to environmental concerns, spans up to 220 ft were chosen to eliminate as many piers as possible. These large spans were made possible through the use of precast, prestressed and post-tensioned, AASHTO Type VI, modified concrete girders composed of haunched pier segments with drop-in spans and fully spliced with draped post-tensioning strands. The resulting continuous structure for Mullica was one of the longest precast, prestressed, post-tensioned spliced concrete girder units in the nation and was subsequently featured in the Fall 2012 issue of *ASPIRE*.™

### Next: Great Egg Harbor

Looking to the future, the NJTA intends to add another long-span concrete bridge traversing the Great Egg Harbor with a 3834-ft-long, 21-span structure with multiple continuous span units, using bulb-tee girders with haunched pier sections and spliced drop-in segments. Span lengths will vary from 148 ft to as long as 250 ft over the navigable channel, making it the longest precast, prestressed, post-tensioned concrete span in the NJTA's inventory.



*The completed Mullica River Bridge. Photo: Parsons Brinckerhoff.*

### Summary

Precast, prestressed, post-tensioned concrete, once an exotic superstructure choice in the northeast, has become an increasingly popular choice among bridge owners seeking to reduce long-term maintenance costs in harsh environments. The NJTA has chosen to stretch convention in the region with challenging bridge designs for challenging infrastructure solutions. **A**

---

*William Wilson is a supervising engineer, structures design for the New Jersey Turnpike Authority in Woodbridge, N.J.*

*Aerial view of the Bass River Bridge. Photo: Hardesty & Hanover.*





# TAKING THE LOAD OFF... Bridges Around the World

## Sustainable Solutions for Longer Lasting Concrete Bridges

### More Efficient Designs

- Less Concrete
- Less Steel
- Fewer/Smaller Foundations
- Lighter for Shipping & Handling

### Enhanced Durability

- Less Permeable
- Less Cracking



Virginia Dare Bridge - North Carolina

Lightweight concrete deck for entire 5.2 mile length of bridge.

Bridge designed for 100 year service life.



HIGH PERFORMANCE LIGHTWEIGHT AGGREGATE

800.898.3772 704.637.1515

www.stalite.com

DYWIDAG-SYSTEMS INTERNATIONAL



**DELIVERING  
SUPPORT &  
INGENUITY**



- DYWIDAG Bonded & Unbonded Post-Tensioning
- External Prestressing
- DYWIDAG Monostrands
- DYNA Grip® Stay Cable Systems
- DYNA Force® Sensor System

Local Presence - Global Competence

www.dsiamerica.com

Bolingbrook, Illinois  
Phone (630) 739-1100

Structural Repair and Strengthening  
Phone (630) 972-7513

Mansfield, Texas  
Phone (817) 473-6161

Long Beach, California  
Phone (562) 531-6161

Tucker, Georgia  
Phone (770) 491-3790

Toughkenamon, Pennsylvania  
Phone (610) 268-2221

Pompano Beach, Florida  
Phone (954) 532-1326

dsiamerica@dsiamerica.com

# Further Improvements in Post-Tensioning Grout Materials

by Gregory Hunsicker, Structural / VSL, and Theodore L. Neff and Miroslav F. Vejvoda, Post-Tensioning Institute

In 2012, the Post-Tensioning Institute (PTI) published the updated PTI M55.1-12, *Specification for Grouting of Post-Tensioned Structures*.<sup>1</sup> The reason for this update was to address concerns related to high chloride content, grout segregation, and to strengthen the provisions to minimize bleed water, as well as ensure proper construction. An article in the Fall 2012 issue of *ASPIRE*<sup>TM</sup> gave a background and details of this update.<sup>2</sup> An addendum to the grouting specification issued in 2013 includes further steps in ensuring quality grouting that is essential for durability of post-tensioned structures.<sup>3</sup>

## 2012 Grouting Specification

A summary of the changes in the 2012 edition of the grouting specification follows.

- Additional and independent field testing for acid-soluble chloride ion (Cl<sup>-</sup>) was introduced to be performed in accordance with ASTM C1152 on the mixed grout once per project and a minimum every 40,000 lb of grout.
- Limits on the Blaine value<sup>4</sup> of the cement used in grout were introduced. The Blaine value is a measure of the cement's fineness. It has a strong effect on the homogeneity of grout. Cements with a Blaine value too low tend to easily flocculate (form lumps)

and may cause segregation. Cements with a too high value require more water and admixtures to wet the surface, and tend to have earlier setting times.

- The bleed testing is enhanced with the introduction of the inclined tube test that is much more realistic reflection of a draped tendon in the structure, with its length of 16 ft at an angle of 30 degrees and with 12 strands in each sample (Fig. 1).
- The wick induced test has also been revised to be more representative of actual conditions in a tendon by increasing the length of the test specimen using a 40-in.-long tube instead of the old short graduated cylinder.
- The range of the constituent materials is now also given for the Class C (prepackaged grouts); in the previous edition, this was only given for the Classes A and B (the basic and engineered site-mixed grouts).
- The grouting operations and production testing were adjusted as well; the wet density and flowability are now measured at the mixer as well as at the outlet so that the grout quality and consistency within the tendon can be monitored (Fig. 2). The flushing of tendons is no longer permitted. Prewetting of ducts inadvertently adds water to the mix and flushing in cases of grout problems creates a situation that is very difficult to repair. Finally, low grouting pressures and no pressurization of the tendons after grouting are recommended.

## Specification Addendum

The changes introduced in the 2012 edition of the PTI specification, if properly followed and enforced, will be very effective in controlling bleeding and the level of chloride in grout. However, research and field investigations by the Florida Department of Transportation (FDOT) and others continue to raise concern regarding the causes of and problems associated with segregated grout. Under some circumstances, the constituents of some prepackaged grouts can separate during grout injection leading to areas where the grout does not harden (for example, "soft grout"). The segregated material has been observed to be corrosive in some cases, even without the presence of chloride.

In June 2013, the PTI M-55 Grouting Committee published *Addendum No. 1 to PTI M55.1-12 Specification for Grouting of*

*Post-Tensioned Structures*<sup>5</sup> to further address the "soft grout" issue. This document is now officially a part of the grouting specification and should be referenced with it.

Ongoing research at the University of Florida at Gainesville is attempting to determine the exact cause(s) of grout segregation. Preliminary findings indicate that the addition of aggregates and inert fillers to the grout mix, and improper storage of grout may contribute to the segregation of the constituent materials.

Other research by FDOT and Florida International University has found that when grout segregation (soft grout) occurs, there is often a very high concentration of sulfate in the segregated material, which is believed to increase the corrosion potential in the tendon.

In response to this research and the ongoing concern about grout segregation, the following changes were included in Addendum No. 1:

- For jobsite (Class A and B) and prepackaged (Class C) grout mixes, the addition of aggregates and inert fillers is now prohibited. These materials can only be used in special Class D grout approved by the design engineer for a specific project need.
- Mineral additives and admixtures shall not contain sulfates.
- The limits for Blaine values for cement were revised to be between 300 to 400 m<sup>2</sup>/kg to more closely match cements produced in the United States.
- Only mineral additives and admixtures specifically listed in the specification may be used. Only undensified silica fume shall be permitted.

Although sulfates in high concentration occur only in the areas of soft grout, no supplemental cementitious materials or chemical admixtures may include sulfates, besides those already contained in the permitted constituent materials. The grout ingredients are limited to those specifically permitted.

## Summary

The PTI M-55 Grouting Committee is actively working with all stakeholders on the next edition of the grouting specification to include the latest knowledge and research. The present specification with the addendum should be referenced by specifiers as it represents the latest developments and research performed in the field. 



Figure 1. The inclined tube test is a large scale bleed test. All Photos: Structural / VSL.



Figure 2. The wet density and flowability are tested at mixer as well as at the the outlet.

Gregory Hunsicker is the division manager of Structural / VSL in Fort Worth, Tex. Theodore L. Neff is the executive director and Miroslav F. Vejvoda is the technical and certification director of the Post-Tensioning Institute in Farmington Hills, Mich.

## References

1. Post-Tensioning Institute. 2012. *Specification for Grouting of Post-Tensioned Structures*, PTI M55.1-12, Farmington Hills, Mich.
2. Neff, T. 2012. "New Specifications for Grouting," *ASPIRE*, Fall, Precast/Prestressed Concrete Institute, Chicago, Ill. p 52.
3. Vejvoda, M. 2013. "Specification Updates for Multistrand Post-Tensioning," *PTI JOURNAL*, August, Farmington Hills, Mich.
4. ASTM International. 2011. *Standard Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus*. ASTM C204-11, West Conshohocken, Penn.
5. Post-Tensioning Institute. 2013. *Addendum No. 1 to PTI M55.1-12 Specification for Grouting of Post-Tensioned Structures*, <http://www.post-tensioning.org/technical.php>, Farmington Hills, Mich.

## Additional References by FHWA

1. FHWA May 2013, "Post-Tensioning Tendon Installation and Grouting Manual," See <http://www.fhwa.dot.gov/bridge/pt/>
2. FHWA November 2013, Technical Advisory 5140.33 "Recommendations for Assessing and Managing Long-Term Performance of Post-Tensioned Bridges having Tendons Installed with Grout Containing Elevated Levels of Chloride," See <http://www.fhwa.dot.gov/bridge/t514033.pdf>

# SILICA FUME IN POST-TENSIONING GROUT

by Tony Kojundic, Elkem Materials Inc. and the Silica Fume Association

Silica fume is a supplementary cementitious material (SCM) that is often used in post-tensioning grout to improve workability and reduce environmental impact. However, raw silica fume—a waste material—often contains debris (wood chips and coal) that can be problematic if not properly removed from the silica fume before it is used in any grout. This article provides guidance to grout producers on purchasing the proper silica fume products to ensure none of this debris enters any grout product.

## Raw Silica Fume

Silica fume is a waste product from the production of silicon metal or ferrosilicon alloy. High-purity silica, wood chips, and coal are fed into a smelter, and silicon metal is produced from the smelting furnace at about 3600°F. As the oxidized vapor cools, it condenses into an amorphous silica that is extracted from the furnace emission stream by large fans. The fans pull the smoke (fume) off the electric-arc furnace, depositing the silica fume in bag-house filters. Along with the silica fume, the large vacuum fans pull some fine wood fibers, wood chips, and coal debris into the filters. This debris in raw silica fume must be removed for many silica fume applications such as SCMs or for fillers in mining belts and in hard rubber wheels found on many grocery and luggage carts.

## Silica Fume Screening

Raw silica fume collected in the bag-house filter is tested in accordance with AASHTO M307 (ASTM C1240), *Standard Specification for Silica Fume Used in Cementitious Mixtures*, prior to any classification, separation, or densification processes. AASHTO M307 allows up to 10% of the silica fume to be oversized particles (those greater than 45 µm), but typically raw silica fume only contains 5 to 6% oversized particles.

Plants employ numerous technologies to remove this oversize portion. Because all silica fume will pass a 45 µm screen, the portion greater than 45 µm is considered debris. Removing this debris is critically important to many applications, including post-tensioning grout.

The small quantity of debris found in AASHTO M307 silica fume poses no problems in conventional concretes containing coarse aggregates. In more-advanced applications,



This photo shows typical +45µm particles found in raw silica fume. (Percent is unknown.) All photos: Elkem Materials Inc.



Debris from silica fume containing an average of approximately 1.5% of particles over 45µm.

such as post-tensioning grout, cleanliness can be ensured by sourcing a silica fume where the debris has been removed or by running the silica fume over a No. 14 mesh screen (catching these slivers) prior to use. This in-house scalping step is often a standard operating procedure for advanced applications, such as post-tensioning grout, to ensure cleanliness of the silica fume prior to use. **A**

Tony Kojundic is a fellow of ACI and business manager for Elkem Materials Inc., Pittsburgh, Pa. He also serves as director of the Silica Fume Association, Lovettsville, Va.

# 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.omniproservices.com/photo-gallery-jeremiah-morrow-bridge.html](http://www.omniproservices.com/photo-gallery-jeremiah-morrow-bridge.html)

Visit this website for pictures and information about the reconstruction of the Jeremiah Morrow Bridge described on pages 12 to 15.

### <http://i-85yadkinriver.com/abouttheproject.html>

This website provides overall information about the I-85 Yadkin River project presented on pages 20 to 22.

### [www.coloradodot.info/projects/pecosoveri70](http://www.coloradodot.info/projects/pecosoveri70)

Information about the Pecos Street over I-70 bridge replacement in Denver, described on pages 24 to 26, is provided on this Colorado Department of Transportation website. A 30-second video shows the SPMT move.

### [www.wsdot.wa.gov/projects/i5/skagitriverbridgereplacement/](http://www.wsdot.wa.gov/projects/i5/skagitriverbridgereplacement/)

This Washington State Department of Transportation website has information about the I-5 bridge span replacement over the Skagit River as presented on pages 29 to 31. Photographs of the construction and a video of the span replacement are available.

### [www.youtube.com/watch?v=ldUap4\\_ivY](http://www.youtube.com/watch?v=ldUap4_ivY)

A time lapse series of the entire girder setting operation for the I-5 bridge span replacement is available at this website.

### [www.flickr.com/photos/wsdot/sets/72157634573080718/](http://www.flickr.com/photos/wsdot/sets/72157634573080718/)

This web site has over 50 photographs showing the construction of the I-5 bridge span replacement.

### [www.fhwa.dot.gov/bridge/nbi/ascii.cfm](http://www.fhwa.dot.gov/bridge/nbi/ascii.cfm)

This website provides access to the National Bridge Inventory data sets as mentioned in the FHWA article on page 32.

### [www.fhwa.dot.gov/infrastructure/asstgmt/invest.cfm](http://www.fhwa.dot.gov/infrastructure/asstgmt/invest.cfm)

The links on this website provide resources for evaluating roadway investments as mentioned in the FHWA article on page 32.

## Sustainability

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

Information about Envision,<sup>TM</sup> a rating system system for sustainable infrastructure, is available at this website.

## 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.

### [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.concretebridgeviews.com](http://www.concretebridgeviews.com)

This website contains 71 issues of *Concrete Bridge Views* (formerly *HPC Bridge Views*), an electronic newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of concrete in bridges.

### [www.fhwa.dot.gov/research/resources/uhpc.cfm](http://www.fhwa.dot.gov/research/resources/uhpc.cfm)

This FHWA website is the location of considerable information about ultra-high-performance concrete including both research and applications.

### **NEW** [www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/13060](http://www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/13060)

A new report titled *Ultra-High Performance Concrete: A State-of-the-Art Report for the Bridge Community* (Pub. No. FHWA-HRT-13-060) is available at this website. The report includes information on materials and production, mechanical properties, and structural design and testing. An extensive list of references is provided.

### [www.abc.fiu.edu/wp-content/uploads/2013/07/ABC-User-Guide-for-posting1.pdf](http://www.abc.fiu.edu/wp-content/uploads/2013/07/ABC-User-Guide-for-posting1.pdf)

This Florida International University website contains a users' guide to the National ABC Project Exchange, which is a nationwide repository of projects that have incorporated Prefabricated Bridge Elements and Systems (PBES) with other innovative strategies to accomplish the objects of accelerated bridge construction.

### [www.trb.org/Publications/Blurbs/168757.aspx](http://www.trb.org/Publications/Blurbs/168757.aspx)

This website contains a new National Cooperative Highway Research Program Synthesis titled *High Performance Concrete Specifications and Practices for Bridges*.

## Bridge Research

### **NEW** [www.trb.org/shrp2/researchreports](http://www.trb.org/shrp2/researchreports)

Are you looking for a research report from the second Strategic Highway Research Program (SHRP2)? Nearly 90 reports organized by focus area and topic are now available as free downloads from this website.

### [http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rpt\\_733.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_733.pdf)

NCHRP Report 733, *High-Performance/High-Strength Lightweight Concrete for Bridge Girders and Decks* presents proposed changes to the AASHTO LRFD bridge design and construction specifications to address the use of lightweight concrete in bridge girders and decks.

### [www.trb.org/main/blurbs/167693.aspx](http://www.trb.org/main/blurbs/167693.aspx) and [www.trb.org/main/blurbs/168046.aspx](http://www.trb.org/main/blurbs/168046.aspx)

These two websites contain the Strategic Highway Research Program 2 reports titled *Innovative Bridge Designs for Rapid Renewal*. The first website has the 870 page prepublication draft. The second website contains the associated ABC toolkit.

# PRESTRESSED CONCRETE BRIDGES



Route 70 over Manasquan River in New Jersey (Photo courtesy of Arora Associates) Alternate design structure utilizes precast caissons, piers, pier caps, and prestressed concrete beams. The bridge was opened to traffic two years ahead of as-designed schedule.

## THE OPTIMUM SOLUTION TO BENEFIT:

**THE PUBLIC** - *Aesthetic, Durable & Safe*

**THE OWNERS** - *Low Maintenance & Life Cycle Costs*

**THE DESIGNERS** - *Well Established Standards & Simple to Design*

**THE CONTRACTORS** - *Familiar Material & Fast to Construct*

**THE ENVIRONMENT** - *Low Energy Content & Sustainable Solution*



Central Atlantic Bridge Associates

1042 North Thirty Eighth Street, Allentown, PA 18104

Phone: (610) 395-2338

Email: [info@caba-bridges.org](mailto:info@caba-bridges.org) • [www.caba-bridges.org](http://www.caba-bridges.org)



Certified Plants At Your Service In The Central Atlantic Region



Bayshore Concrete Products

1134 Bayshore Road  
Cape Charles, VA 23310  
Phone: (757) 331-2300  
Fax: (757) 331-2501

[www.usacivil.skanska.com](http://www.usacivil.skanska.com)

Email: [Chad.Saunders@skanska.com](mailto:Chad.Saunders@skanska.com)



Northeast Prestressed Products, LLC.

121 River Street  
Cressona, Pennsylvania 17929  
Phone: (570) 385-2352  
Fax: (570) 385-2404

[www.nppbeams.com](http://www.nppbeams.com)

Email: [info@nppbeams.com](mailto:info@nppbeams.com)



Jersey Precast Corporation

853 Nottingham Way  
Hamilton Township, NJ 08638  
Phone: (609) 689-3700  
Fax: (609) 689-3797

[www.jerseryprecast.com](http://www.jerseryprecast.com)

Email: [jrzprecast@aol.com](mailto:jrzprecast@aol.com)



Newcrete Products, Inc.

P.O. Box 34  
301 Plum Creek Road  
Roaring Spring, PA 16506  
Phone: (814) 224-2121

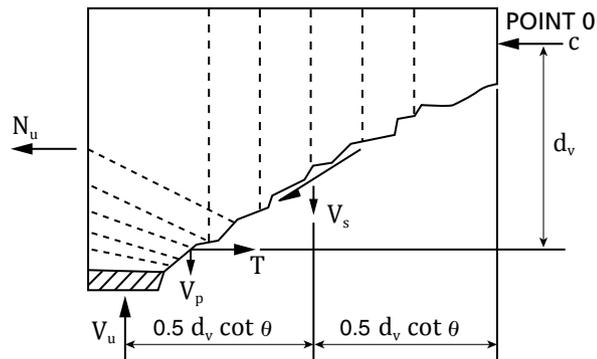
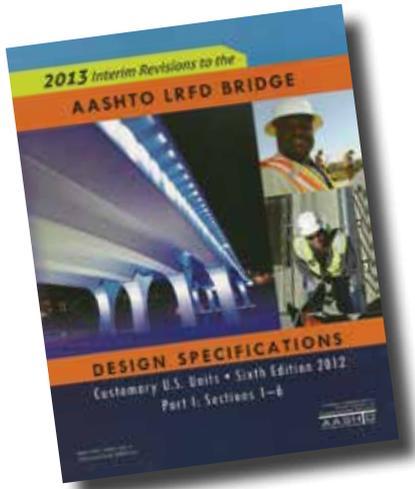
[www.newcrete.com](http://www.newcrete.com)

E-mail: [ggorman@nesl.com](mailto:ggorman@nesl.com)



# Sectional Design Model: Maximum or Concurrent Force Effects?

by Dr. Dennis R. Mertz



again along with  $N_u$  and in one case  $T_u$ . This interaction is illustrated in the free-body diagram, adapted from the *LRFD Specifications*, shown above.

Summing moments about point 0 in the figure as detailed in *LRFD Specifications* Article C5.8.3.5, yields Equation 5.8.3.5-1, shown below, as used for sections not subject to torsion.

$$A_{ps}f_{ps} + A_s f_y \geq \frac{|M_u|}{d_v \phi_f} + 0.5 \frac{N_u}{\phi_c} + \left( \left| \frac{V_u}{\phi_v} - V_p \right| - 0.5V_s \right) \cot \theta$$

For sections subject to combined shear and torsion, Equation 5.8.3.6.3-1, shown below, is used.

$$A_{ps}f_{ps} + A_s f_y \geq \frac{|M_u|}{\phi d_v} + \frac{0.5N_u}{\phi} + \cot \theta \sqrt{\left( \left| \frac{V_u}{\phi} - V_p \right| - 0.5V_s \right)^2 + \left( \frac{0.45 p_h T_u}{2A_c \phi} \right)^2}$$

The three equations discussed here represent a single point in time, as shown in the free-body diagram. Thus, the force effects should be concurrent values due to a common load condition. In general, when checking shear, the maximum shear is used with the other concurrent force effects; when checking

moment, the maximum moment is used with the other concurrent force effects. Theoretically, at each section, each of the maximum force effects should be checked with its other concurrent forces though this is not typically done.

Equation 5.8.3.4.2-4, for  $\epsilon_s$ , is applied at sections along the beam (typically 1/10<sup>th</sup> points) to determine the shear resistance of each section. For each section, the maximum shear and the other concurrent force effects at that section are used in the equation.

Equations 5.8.3.5-1 and 5.8.3.6.3-1, for the required longitudinal reinforcement, are again applied for sections along the beam to determine the required reinforcement at each section. Again, for each section, the maximum shear and the other concurrent force effects at that section determine the required longitudinal reinforcement.

The various strength limit-state force effects (in other words, the sum of the factored force effects from the governing strength limit-state load combination),  $M_u$ ,  $V_u$ ,  $N_u$ , and  $T_u$ , in the LRFD equations, do not represent the maximums for the section due to different load conditions. They represent the maximum force effect under consideration along with the other concurrent values for the single governing load condition at each section. **▲**

Since the discussion in the Fall 2013 issue of *ASPIRE™* regarding how cracked concrete carries shear, readers raised questions about the application of several equations in Article 5.8.3, Sectional Design Model, of the *AASHTO LRFD Bridge Design Specifications*. In several equations, the variables  $M_u$  and  $V_u$  appear along with  $N_u$  and in one case  $T_u$ . Are these concurrent values, maximum values, or what?

Applying the modified-compression field theory model, the net longitudinal tensile strain in the section at the centroid of the tension reinforcement,  $\epsilon_s$ , is estimated using *LRFD Specifications* Equation 5.8.3.4.2-4, shown below. This strain is then used to determine  $\beta$ , the factor indicating the ability of diagonally cracked concrete to transmit torsion and shear, and  $\theta$ , the angle of inclination of the diagonal compressive stresses.

$$\epsilon_s = \frac{\left( \frac{|M_u|}{d_v} + 0.5N_u + |V_u - V_p| - A_{ps}f_{ps} \right)}{E_s A_s + E_p A_{ps}}$$

The variables,  $\beta$  and  $\theta$ , and their influence on shear resistance, are discussed in the Fall 2013 issue. Equation 5.8.3.4.2-4 includes  $M_u$  and  $V_u$  along with  $N_u$ .

For all the section design models, in determining the required longitudinal reinforcement due to the interaction of the force effects, the variables  $M_u$  and  $V_u$  appear

## EDITOR'S NOTE

If you would like to have a specific provision of the *AASHTO LRFD Bridge Design Specifications* explained in this series of articles, please contact us at [www.aspirebridge.org](http://www.aspirebridge.org).

TAKE YOUR PROJECTS  
**LARSA 4D**  
TO THE NEXT DIMENSION



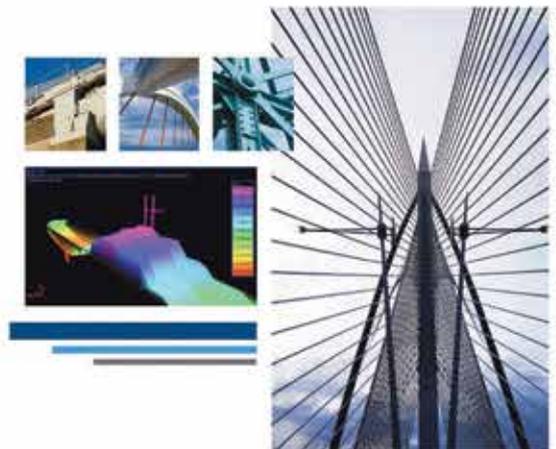
The Complete Software for Bridge Design, Analysis & Construction

## BRIDGE SERIES

4D BRIDGE PLUS | 4D BRIDGE | 4D BRIDGE pLT

Pioneers of 4D, LARSA's mission has been to lead innovation in analysis and support. In LARSA 4D, a rock-solid analysis engine with an intuitive user interface is coupled with the latest computing technology. "Features on Demand" allows LARSA's support team to deliver new tools on the spot in response to client needs. LARSA 4D has proven itself an invaluable asset in today's fast-track projects.

The trusted company standard at CH2M HILL, FIGG, HDR, International Bridge Technologies, Parsons Brinckerhoff, T.Y. Lin International, and many other leading firms around the world.



1-800-LARSA-01

for a free trial license visit [www.LARSA4D.com](http://www.LARSA4D.com)

Harbor Drive Pedestrian Bridge | T.Y. Lin International Group  
Photo by Brooke Duthie, courtesy of T.Y. Lin International



## *Create high-performance structures while reducing your environmental footprint.*



*The rebuilt Minneapolis I-35W bridge contains Holcim Envirocore cement.*

When Minneapolis' I-35 bridge collapsed and needed to be rebuilt, experts chose Holcim's high-performance Envirocore™ products. Envirocore can be used to create concrete that is less permeable, more durable and easier to work with. Envirocore can also help you achieve LEED points for certification.

When you look at life cycle assessments, concrete can offer lasting environmental benefits. Concrete uses local materials, requiring less transportation and emissions. It has high thermal mass, which improves energy efficiency and comfort. Concrete's light color reduces urban "heat island" effects and air conditioning requirements. Many concrete structures have 100-year life spans and concrete can be reused after demolition.

Our technical service engineers can help you determine what Envirocore products are right for your next concrete project. For superior performance and reduced environmental impact, give us a call today.

888.646.5246 [www.holcim.us](http://www.holcim.us)