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THE CONCRETE BRIDGE MAGAZINE

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SR 520 Eastside Transit and HOV Lanes Project *Bellevue, Washington*

THE VALUE OF ABC

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Siskiyou County, California

PETALUMA RIVER BRIDGE REPLACEMENT ON US 101
Petaluma, California

SR 520 EVERGREEN POINT FLOATING BRIDGE
LOW-RISE SUPERSTRUCTURE
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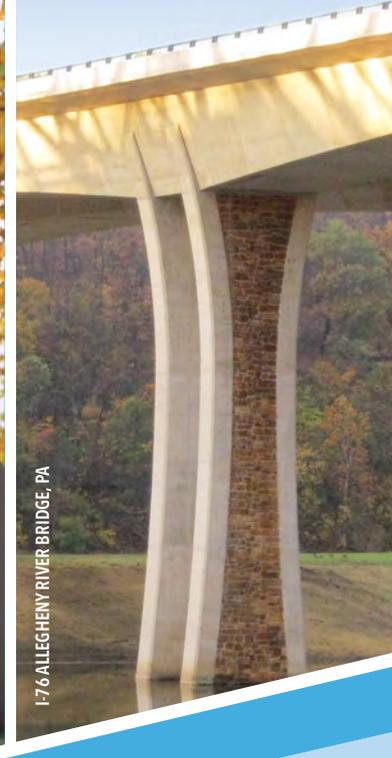
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NEW I-35W BRIDGE, MN



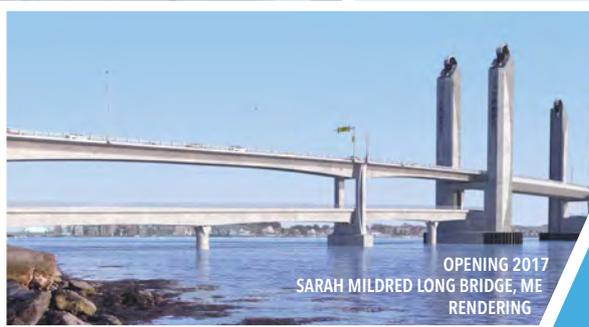
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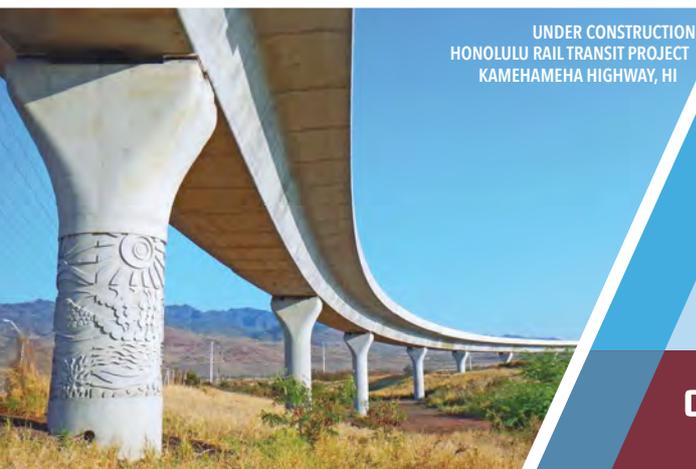
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Photo: Granite.

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Photo: PCI

Throughput is not the measure of efficiency

Study what is real efficiency and streamline every step to make ABC our new bridge construction norm

William Nickas, *Editor-in-Chief*

Throughput time is a measure used at every jobsite and manufacturing plant to track the time needed for an element to pass through the assembly process. It can vary depending on how many yards of concrete had to be placed or how much reinforcement needed to be tied. Other indicators of productivity used by a plant may be the amount of payroll attributed to placing a cubic yard of concrete, or equipment utilization rates for a given measurement period.

Indicators and measures of quality control influence many aspects of our inspection processes, which also impact throughput time. Time for the owner's inspector to check for contract document conformance or create test cylinders relate to the efficiency of the job. Suppliers, contractors, and owners all have to coordinate to make the total system work effectively. We know what influences efficiency, but how do we measure real efficiency on a project?

The old adage "we are all uniquely doing the same thing" has been stuck in my head for a longtime. I shared that with my neighbor Frank Boerger, who is a manufacturing database consultant. The conversation drifted into how corporations routinely measure the wrong thing.

Adding contractors to the focus article rotation of this magazine has allowed our readers to look at what some of the traits are that separate the best builders from some very good ones. It is all about resource allocation and reducing nonvalue-added processes. Let's start really studying efficiency.

While everyone has company secrets on means and methods that lead to competitive advantages, let's all agree on a few long-term improvement goals that new technologies may help us work toward the following goals:

- Zero queue time on our job sites; no crane delays, no idle crews, no wrong or missing materials, no misaligned connections, no prior stage construction out of theoretical position/tolerances.
- In our bridge supplier plants, zero queue time between work stations within the manufacturing facility.
- The duration of holding inventory to be reduced to avoid excess capitalization and yard and jobsite storage costs.
- A business environment at all stages promoting the goal for zero defects thus minimizing rework and nonvalue-added project costs.
- Product and system inspections that are embedded

Let's first look at four critical time intervals:

Process Time. The period needed to create something from raw ingredients. This includes several activities for bridge construction such as the time to assemble the processed materials into the bridges manufactured components or the time for the contractor to assemble components and systems into the final bridge.

Inspection Time. This is the time used to inspect the raw materials, including the work-in-progress and the finished bridge.

Move Time. The time to get the raw materials to the processing plant followed by the period of time when the product is moved from the plant to the manufacturer or site. This also includes the effort between manufacturing stations including the post-processing and rework area.

Queue Time. This is the time spent waiting for one of the above three activities.

in the process to reduce repeat issues. Quality assurance testing and compliance testing that also identifies root cause issues.

Accelerated bridge construction (ABC) requires a new set of efficiency measures. Designers and contractors are communicating better to streamline ABC installations with minimal end-user impacts as an external measure of efficiencies. It is time to rework our internal bridge industry tenants to lower ABC costs, while increasing quality, and start measuring real internal efficiencies. Perhaps our contractors and concrete bridge suppliers and manufacturers should take a fresh look at these past successes and details.

Now, here is your assignment, read a short synopsis of the book called "The Goal" by E. M. Goldratt and J. Cox. You can find a summary by Chris Hourigan of the University of South Florida on synchronized manufacturing. It speaks to this concept of real measures of efficiencies. See: www.maaw.info/ArticleSummaries/ArtSumTheGoal.htm.

Editor-in-Chief
William Nickas • wnickas@pci.org

Managing Technical Editor
Dr. Reid W. Castrodale

Contributing Editor
Dr. Henry G. Russell

Program Manager
Nancy Turner • nturner@pci.org

Associate Editors
Emily B. Lorenz • elorenz@pci.org
Craig A. Shutt

Layout Design
Tressa A. Park

Editorial Advisory Board
William Nickas, *Precast/Prestressed Concrete Institute*
Dr. Reid Castrodale, *Castrodale Engineering Consultants PC*

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The SR 520 Eastside Transit and HOV Lanes Project in Bellevue, Wash., was bid as a design-build project in a joint venture of Granite and PCL. Photo: Granite Construction.

Ad Sales
Jim Oestmann
Phone: (847) 838-0500 • Cell: (847) 924-5497
Fax: (847) 838-0555 • joestmann@arlpub.com

Reprints
Nancy Turner • nturner@pci.org

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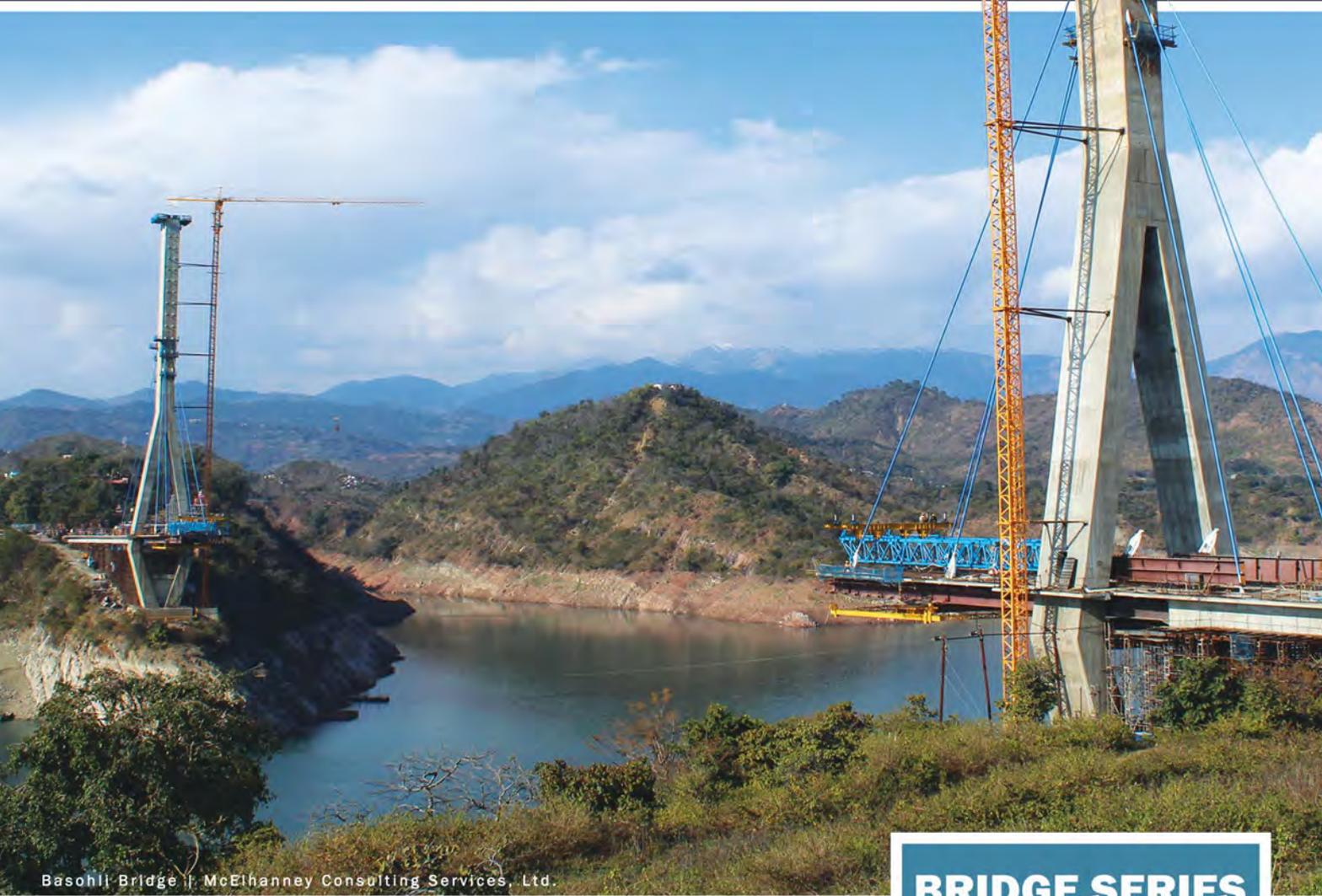
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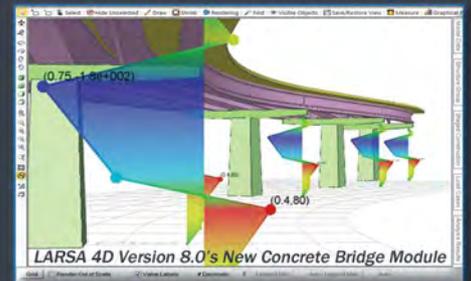
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CONTRIBUTING AUTHORS



Dr. Oguzhan Bayrak is a professor at the University of Texas at Austin. Bayrak received the University of Texas System Board of Regents' outstanding teaching award in 2012 and was inducted into the university's Academy of Distinguished Teachers in 2014.



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.



Reggie Holt is a senior structural engineer at the Federal Highway Administration (FHWA) and manages the concrete bridge program at FHWA headquarters in Washington, D.C.



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.



Dr. Henry G. Russell is an engineering consultant who has been involved with the application of concrete in bridges for 40 years. He served as the Managing Technical Editor of *ASPIRE™* from the first issue in 2007 through the Fall issue of 2014.

CONCRETE CALENDAR 2016-2017

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

April 11-12, 2016
ASBI 2016 Grouting Certification Training
J. J. Pickle Research Campus
Austin, Tex.

April 17-21, 2016
ACI Spring 2016 Concrete Convention and Exposition
Hyatt Regency & Wisconsin Center
Milwaukee, Wis.

April 20-22, 2016
2016 DBIA Design-Build in Transportation Conference
Charlotte Convention Center
Charlotte, N.C.

April 24-26, 2016
2016 PTI Convention
Renaissance Long Beach Hotel
Long Beach, Calif.

May 24-25, 2016
ASBI Construction Practices Seminar
Renaissance Boulder Flatiron Hotel
Broomfield, Colo.

May 27, 2016
CRSI HONORS Design and Construction Awards
Call for entries deadline

June 6, 2016
54th Annual PCI Design Awards
Submission site opens

June 6-10, 2016
International Bridge Conference
Gaylord National Resort & Convention Center
National Harbor, Md.

June 26-30, 2016
AASHTO Subcommittee on Bridges and Structures Annual Meeting
Minneapolis Marriott City Center
Minneapolis, Minn.

June 30, 2016
PCA 2016 Concrete Bridge Award Competition
Call for entries deadline

July 18-20, 2016
First International Interactive Symposium on UHPC
Des Moines Marriott
Des Moines, Iowa

July 25-29, 2016
PCA Professors' Workshop
PCA Campus
Skokie, Ill.

July 31-August 4, 2016
AASHTO Subcommittee on Materials Annual Meeting
Hyatt Regency Greenville
Greenville, S.C.

August 28-31, 2016
AREMA 2016 Annual Conference & Exposition
Hilton Orlando
Orlando, Fla.

September 1, 2016
fib Symposium 2017
Call for papers deadline

October 6-9, 2016
PCI Committee Days and Membership Conference
Loews Chicago O'Hare
Rosemont, Ill.

October 23-27, 2016
ACI Fall 2016 Concrete Convention and Exposition
Marriott Philadelphia
Philadelphia, Pa.

November 8-9, 2016
ASBI 28th Annual Convention
Long Beach Convention and Entertainment Center
Westin Long Beach Hotel
Long Beach, Calif.

November 21-23, 2016
fib Symposium 2016
Cape Town, South Africa

January 8-12, 2017
Transportation Research Board 96th Annual Meeting
Walter E. Washington Convention Center
Washington, D.C.

January 17-20, 2017
World of Concrete 2017
Las Vegas Convention Center
Las Vegas, Nev.

February 28-March 4, 2017
PCI Convention and National Bridge Conference at The Precast Show
Cleveland, Ohio

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TEAMWORK, PARTNERSHIPS BRING SUCCESS

Granite Construction thrives on complex, expansive projects thanks to its methodical approach to developing teamwork in every delivery format and through joint ventures

by Craig A. Shutt

Since its founding in the early 1900s, Granite Construction has embraced the toughest challenges on the largest projects, from rail systems to freeway spans and waterway crossings. No matter the delivery method or construction issues, Granite's methodical approach has led it to larger, more-complex projects that require innovative approaches and close attention to logistics.

Focusing on logistics has become critical as bridge and infrastructure owners embrace more comprehensive, expansive projects. "We consistently apply diligence, perseverance, attention to detail, and good work habits to ensure high-quality projects and excellent customer service," says Brian Dowd, vice president of business development. "We encourage this effort from the time we begin pursuing a project through construction and closeout."

That focus on quality includes the materials it uses, including precast concrete, notes Tom Boyle, project executive. "Most engineers and contractors understand the advantages precast concrete construction can provide with regard to quality, but Granite looks beyond the precasting facility to the actual construction in the field for ways to incorporate quality into the delivery process. Extensive training and dedicated QC [quality control] professionals help the Granite team deliver quality and minimize costly rework."

The Watsonville, Calif.-based company has especially found success in recent years with alternative delivery methods, including design-build, construction manager/general contractor (CM/GC), and public-private partnerships



The Pennsylvania Rapid Bridge Replacement Project features a consortium of firms in a public-private partnership. This photo shows the West Cruickshank Road Crossing. All Photos: Granite Construction.

(P3s). "Alternate procurement projects allow Granite to add innovation to the design of each project," explains Boyle. "These ideas allow Granite to bring added value to these projects that is recognized by owners as they evaluate proposals." They often score proposals higher that provide reduced long-term maintenance, he notes, as well as those that reduce impacts to traffic, reduce environmental impacts, and provide other benefits.

Rapid Replacement Project

A current example is Pennsylvania Department of Transportation's (PennDOT's) Rapid Bridge Replacement Project, an \$899-million P3 project for which Granite is working in a joint venture with Walsh Construction Co. Plenary Group USA Ltd. and Walsh Investors are providing financing and long-term maintenance. HDR serves as lead designer, Walsh Infrastructure Management will maintain the bridges, and PennDOT will perform routine maintenance.

The 558 geographically dispersed bridges range in length from 40 to 75 ft, mostly in rural regions, according



Precast concrete girder placement for the Ripple Road Crossing over Long Run.

to Joseph McIlhinney, construction manager in the Harrisburg, Pa., office. The work began in May 2015 and contains two phases: construction of early-completion bridges (ECB) followed by remaining eligible bridges (REB). Both phases feature a variety of precast concrete girder types to speed construction. PennDOT handled preliminary design, right-of-way permitting, environmental permitting, and utility relocation for the ECB, while Granite is handling all but right-of-way needs for the REB.

"PennDOT chose the P3 method to accelerate the replacement of the bridges and facilitate efficiencies in design and construction," he says. The result was a 20% savings in costs over the life of the concession period compared to PennDOT handling those duties itself.

Innovation Drives Firm

Granite has provided innovations on a variety of projects. On the Hathaway Bridge design-build project in Panama City, Fla., for instance, Granite used 60-in.-diameter prestressed concrete cylinder piles up to 130 ft long. It

marked the first use of the piles on the east coast. "These large-diameter piles resulted in a more economical substructure design than was developed by other teams for this project," Boyle says.

Each pile was designed with thirty-five, 0.6-in.-diameter, 270-ksi strands and 7 ksi concrete. "Using prestressed cylinder piles eliminated post-tensioning used in spun-cast cylinder piles to join pile segments together," he explains. "This eliminates an area of potential corrosion that occurs with spun-cast piles."

On the Jewfish Creek design-build project near Key Largo, Fla., which was completed in 2008 well before the advent of Florida I-beams, Granite used modified Florida bulb-tee beams that were 72 in. deep for all spans other than at the channel. The beams were designed with a 4½-ft-wide top flange to reduce the formed deck area, a 6½-in.-thick web to provide additional cover for steel, and a typical 2-ft 4-in.-wide bottom flange. "This beam offered a very efficient section for the 102- to 107-ft-long spans."

Such results make owners open to new ideas, and Granite encourages that. "We prefer alternative delivery options because they're more competitive on key issues," says Chris Deane, design-build project manager in the Everett, Wash., office. "We can create a better product for both owners and users." Kevin Graf, construction engineering manager in the Lewisville, Tex., office, agrees. "I've been involved in only one design-bid-build in the past 10 years. For projects in Texas, we prefer design-build."

Texas Work Booming

Texas construction is definitely booming, Graf notes. "There are a lot of mega jobs underway in Texas because the government is focused on upgrading the infrastructure. P3 projects are helping to move those forward faster, and design-build ensures they are efficiently designed and built."

An example of this booming construction is the \$1.1-billion I-35 Express Project in Dallas and Denton Counties. The design-build project covers 30 miles through eight cities



The Ripple Road Crossing over Long Run is part of the Pennsylvania Rapid Bridge Replacement Project and features precast concrete girders and bridge components. Note the use of a large, rubber-tire hydraulic crane with single-pick diagonal slings to erect the girder from one end.

and two counties and will alleviate congestion in the heavily traveled corridor. Intersections will feature Texas-designed 54-in.-deep (TX54) prestressed concrete girders. "The TX54 is our beam of choice for highway bridges," says Graf. "It offers a good span length without requiring huge cranes."

For a 1-mile-long bridge crossing a lake and an adjacent roadway, a TX70 will be used, weighing 1000 lb/ft. "We could stretch it over marine areas to cut costs on the marine infrastructure and construction time," said Graf.

With the design-build format, Granite could map out the key critical-path areas and create packages of small areas of focus, such as bridge widenings that could be finished quickly using TX28 or TX34 prestressed concrete girders. The project was divided into four geographical segments, with three construction companies (including Archer Western Contractors and The Lane Construction Corp.) working as a joint venture.

Combining Cultures

"The project was too much of a monster to do as one project," Graf says. But all three companies worked on each segment, combining forces to maximize their skill set. "It wasn't a line-item joint venture, so the tricky part was combining three cultures and finding ways to work together as a team. By focusing on the work at hand and establishing strong communication lines, it works out."

There are benefits to such partnerships, he notes. "Everyone has different ways of doing things, so everybody learns



from each other in some ways. If we learn that there are better ways of doing things that we do routinely, we will adopt what works best and keep using those ideas afterward."

Partnerships can involve more than construction companies, notes Boyle. "Larger projects lend themselves to custom equipment, where the investment can pay a return in increased productivity and reduced costs," he explains. "During the proposal phase, we partner with equipment manufacturers and suppliers to explore potential equipment options and enhancements that could provide a competitive advantage."

Granite has long encouraged a feeling of entrepreneurial leadership to mitigate its large size. "We build capability through continuous learning and remaining flexible and open to possibilities," says Dowd. "We encourage decisions to be made at the lowest level possible. Each business-unit leader, whether a regional manager responsible for a business that covers an entire state or a project manager, knows to continually seek the most innovative way to build our construction projects."

Each unit leader is supported by a host of resources, such as the construction services group, which provides engineering, design coordination, or



Pennsylvania Rapid Bridge Replacement Project utilizing spread boxes and epoxy-coated reinforcement.

scheduling expertise. Each year, the firm presents an award and a \$2500 prize to the employee that developed the best innovation. "This not only highlights the innovation throughout the company but gets our employees engaged in thinking about how they might develop innovations."

This annual operations meeting also provides awards to top projects in several categories of specific criteria, such as developing the best technical solutions while meeting high standards for safety, environmental issues, quality, ethics, and productivity.

Joint Ventures Blossom

Granite's joint-venture partnerships develop based on the project's size, risk profile, and expertise needed, says Deane. His recent work on the SR 520 Eastside Transit and HOV [high-occupancy vehicle] Lanes Project in Bellevue, Wash., was completed in conjunction with PCL Construction. The \$306-million size was "on the fence" of a joint-venture size, but the requirements of the project and its location encouraged the partnership.

The work, in an affluent area where the road served as the only access to high-end homes, included widening 2.8 miles of roadway plus replacing

two overpasses and other structures. The team also constructed general-purpose and HOV concrete access ramps along with three lid structures (tunnel like) over the road, with two providing access to new transit stops.

"This job fit well with PCL due to our individual expertise," he says. "It also gave us a smaller project to work on to see how we fit together for future partnering opportunities. We could get to know each other on a smaller scale."

A key part of the planning involved a task force that worked with the community and Washington State Department of Transportation to gain feedback on desired goals and amenities. "It was challenging to fit everything into the budget," he says. "We wanted to meet their needs but also manage expectations."

Working with communities has become a much larger part of the process, and Granite encourages that interaction at every level. "We recognize that the best-run business units and projects are the result of the highest functioning teams," says Dowd. "One very important way to nurture this culture of teamwork is by engaging as a team in the communities in which we work. We encourage and support our employees to engage with local communities."

Granite's 100-plus-year History

Granite Construction's history dates to the 1870s when granite was discovered in Watsonville, Calif. John T. Porter, his son Warren, and Arthur R. Wilson purchased the Logan Quarry and began to supply granite to builders. In 1900, the Granite Rock Co. was incorporated, followed in 1922 by the establishment of the Granite Construction Co., which focused most of its efforts on quarrying.

The firm adapted through the Great Depression and World War II, working on many infrastructure projects for the government. It purchased the Perkins Quarry and American Sand & Gravel in Sacramento, Calif., which laid the groundwork for its growth across the country. In the 1970s, it expanded to take on subway work, working on projects from San Francisco, Calif., to Washington, D.C.

Today, Granite is publicly traded and one of the 25 largest construction companies in the United States. Divided into four business segments (Construction, Large Project Construction, Construction Materials, and Real Estate), it reported revenues of \$2.3 billion in 2014. It has about 1700 salaried employees located in offices nationwide. It also operates a variety of sand and gravel quarries in western states.

Meetings a Must

This responsiveness to stakeholder feedback and attention to detail results from one key activity: meetings. "The key to success and our ability to overcome challenges is to have a lot of meetings," says Deane. On the SR 520 project, a variety of task forces and constructability reviews worked through every detail at each point. "Our plans are robust; we often produce 3- to 4-in.-thick binders of work scope." That can include pre-activity meetings with all qualified people, area-coordinator meetings, weekly and daily conferences for foremen, quality-incident reviews, and others.

Attention to detail is apparent on the Tappan Zee Bridge project currently



Precast concrete deck panels ready for installation on the Tappan Zee Bridge, the 3.1-mile-long, \$3.9-billion bridge in New York. Placement of precast concrete deck panels that are 12 ft long and 11 in. thick, and range in width from 22 to 45 ft.

Granite's Core Values

"You can't talk about Granite's culture without talking about our Code of Conduct and Core Values," says Brian Dowd, vice president of business development. Based on a document produced about 1940 by founder and first president Walter "Pops" Wilkinson, the code is ever present on walls and desks.

Included are key tenets in nine Core Values: Safety, Honesty, Integrity, Fairness, Accountability, Consideration of Others, Pursuit of Excellence, Reliability, and Citizenship. They include statements such as "Boldly contend for that which is right and firmly reject that which is wrong" and "Review each night the entire day's work, considering all mistakes and shortcomings, resolve to improve tomorrow, never making the same mistake twice."



As part of the Pennsylvania Rapid Bridge Replacement Program, membranes were used to enhance performance in concrete substructure abutments.

quality-control and quality-assurance teams.

Many of the challenges involve the basic logistics of such a large project. "The sheer size of the bridge makes it daunting," he says. "The logistics of moving workers and materials to where they are needed on a daily basis is one of the biggest challenges."

The project's first phase is scheduled to open later this year. "We're now well into the construction phase, with only a few design issues left, so we're mostly focused on the technical work groups and construction issues. Every element has its own challenges." The team also is quick to find innovations. "The lessons we learn on an early section are put to immediate use as we move into the next segment."

underway, in which the new 3.1-mile, \$3.9-billion New York bridge is having approximately 7000 precast concrete deck panels installed for the driving surface on the approach spans and the river crossing. The panels had to provide a 100-year service life, which required added attention to embeds, reinforcement, and other detailing. Special concrete mixture proportions were created to ensure the panels resisted corrosion.

"We had rigorous preproduction testing to approve the final design criteria," says Chris Leykam, project manager at Granite's Brooklyn location. Leykam's job is to manage technical work-group meetings and details that arise with issues related to the development of the specifications. Achieving that goal requires meetings with representatives from the client, designers, construction team, and

Encouraging an entrepreneurial spirit while focusing on team building ensures Granite will continue to innovate. "The magic of our culture has been passed from generation to generation," says James H. Roberts, CEO. "As the generations go on, Granite becomes stronger. We invest heavily in people because they are our greatest strength." 

US 93 Wildlife Overpass Bridges

by David Benton, Arizona Department of Transportation



Elevation view of the US 93 Wildlife Overpass Bridge. Photo: Arizona Department of Transportation.



A wildlife fence channels sheep toward the overpass. Photo: Arizona Department of Transportation.

Just south of the Arizona-Nevada border, in the shadow of the famous Hoover Dam at the Colorado River and the adjacent iconic Mike O'Callaghan-Pat Tillman Memorial Bridge, sit three smaller bridges serving a purpose of a different kind. In 2008, the Arizona Department of Transportation (ADOT) began construction of a 15-mile segment of US 93 to provide improvements to the existing highway to meet future capacity and operational needs. As part of the project, a key issue to be addressed dealt with the desert bighorn sheep habitat, which the existing US 93 alignment had fragmented, resulting in numerous vehicle collisions involving the sheep.

A wildlife study performed by the Arizona Game and Fish Department provided key information regarding the behavior and crossing habits of desert bighorn sheep in the project area. The sheep study yielded information as to the sheep's preference to

cross at the roadway level at ridgeline intersections, rather than through the existing culverts or waterway bridges that intersected the existing alignment. The study also revealed that a significant amount of crossings, approximately 82%, happened at three locations in the 15-mile segment of the project.

From the study, and with recommendations from a technical advisory committee formed as part of the US 93 roadway project, it was decided that wildlife structures over traffic at the three locations of interest would be beneficial to protect both the travelling public and the desert bighorn sheep. Past projects in the state to address wildlife movements involved wildlife underpasses with considerable success. However these wildlife bridges would be the first of their kind in the state of Arizona, serving wildlife movements over a highway.

Three two-span bridges constructed of precast, prestressed American Association of State Highway and Transportation Officials (AASHTO) Type V girders were chosen based on many factors including ease of construction over an existing roadway, the desire to eliminate falsework, and cost. The bridge lengths were set at 202 ft and varied in width from 50 ft at two locations, to 100 ft at the third. The conventional bridge deck was covered with a 6-in.-thick, non-erodible soil system to match the surrounding habitat. To facilitate the use of the bridges by the sheep, a specific wildlife fence was used to channel the sheep towards the bridges. Current data as of February 2015 have documented over 5000 crossings by sheep identified by game cameras mounted on the bridges. An estimated 82% reduction of vehicle/sheep collisions compared to previous data serve as evidence of the project's success. **A**

Desert bighorn sheep use the new crossing. Photo: Arizona Game and Fish Department.



David Benton is the bridge design manager, Bridge Group, Arizona Department of Transportation in Phoenix, Ariz.

A pair of animals safely navigating the overpass. Photo: Arizona Game and Fish Department.





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PERSPECTIVE

ASPIRE™

10th Anniversary and Counting



by Dr. Henry G. Russell

This year marks the tenth year that *ASPIRE*™ has been produced. The inaugural issue was published in Winter 2007 after more than a year of assembling staff, sponsors, advertisers, writers, mailing lists, and articles. This *Perspective* traces the journey of *ASPIRE* from an unknown magazine to today's publication with 21,500 subscribers.

The Mission

The mission was to provide the first publication devoted exclusively to delivering both inspirational and practical information about concrete bridge design and construction. The name of *ASPIRE* was selected because of its dictionary meaning of "a strong desire for high achievement" and to "strive toward an end."

ASPIRE was and still is a collaborative effort of the concrete bridge industry with support of the industry's associations. As such, the magazine strives to present the achievements of the industry whether in segmental concrete construction; precast, prestressed concrete construction; or cast-in-place concrete construction. We also set out to recognize the owners be they federal, state, county, authority, or municipality.

The Response

As we embarked on the journey, we had no idea what the response would be or how long the journey would last. This was 2007 and the recession was on the horizon. It only took a few issues and we had our readers' responses:

'The inaugural issue was outstanding.'

'Congratulations on a great first issue of ASPIRE.'

'I am very impressed with your new magazine.'

'I have found the articles informative, offering new ideas to implement.'

'Congratulations on a great inaugural year and your vision that has been realized.'

For the first few issues, we used freelance writers to prepare some of the articles because nobody had heard of *ASPIRE* and potential authors were reluctant to contribute articles. However, as word spread, that changed and, today, the majority of our articles are written by bridge engineers directly involved in the projects.

The Changes

Over the years, we have made gradual changes in content to improve our effectiveness.

In Winter 2008, we introduced two new series to provide a wider array of features. *Safety and Serviceability* was added in the light of some bridge accidents. *Concrete Connections* provided web addresses for more information on featured topics, research reports, and other resources.

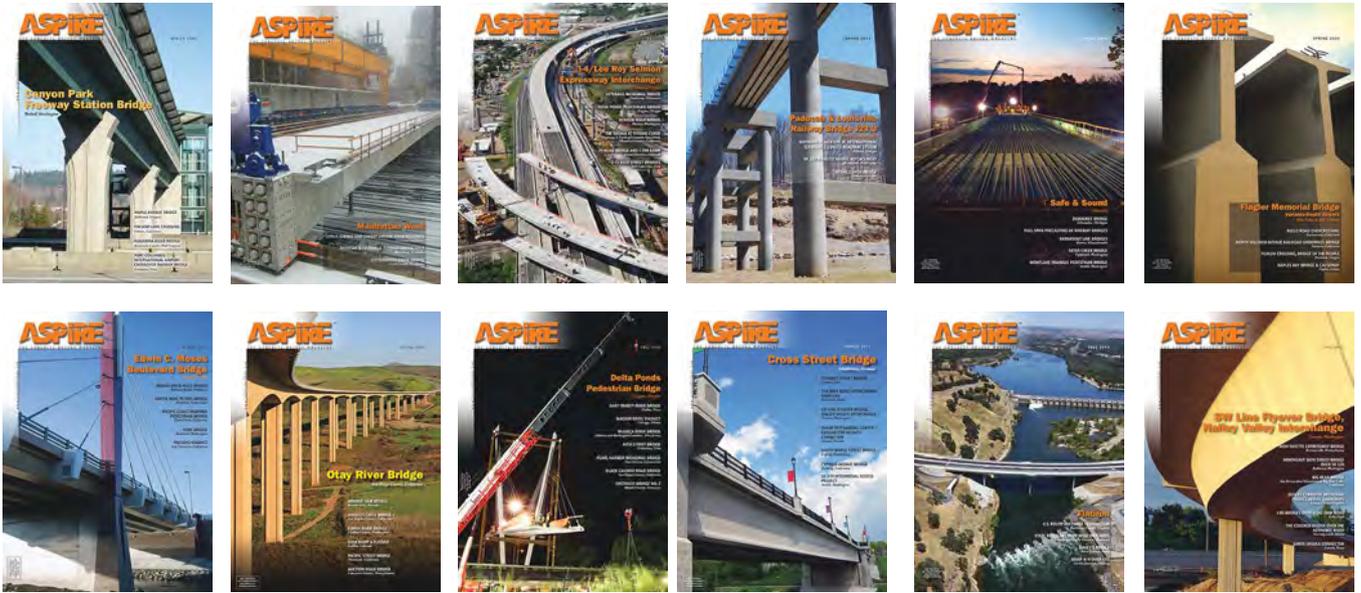
One aspect of the concrete bridge market that we did not initially recognize was that many old concrete bridges were being restored to prolong their service life using modern technology; and the series called *Maintenance, Repair, and Rehabilitation of Concrete Bridges* was introduced in Winter 2009. The name was later changed to *Concrete Bridge Preservation* to provide a broader scope.

In Winter 2011, we introduced *Creative Concrete Construction* articles. These articles generally have a length of one page and provide an avenue to describe creative techniques and methods used on a particular project.

In Summer 2012, we added a new feature called *Accelerated Bridge Construction* to address this evolving approach to bridge construction. This separate series was concluded in Fall 2014. Bridges that use accelerated

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bridge construction are now included in the project profile articles.

Initially, our *Focus* article only featured bridge designers. Yet, there was another player in the industry who was equally important—the contractor. So in 2014, we introduced articles about contractors in the Spring and Fall issues, while retaining the focus on designers in the Winter and Summer issues.

In the Summer 2014 issue, we announced the all-new, electronic version of *ASPIRE*, available for laptops, tablets, and smartphones from aspirebridge.org. This also facilitated the addition of a search option for all issues, a feature that readers had requested.

In the Fall 2014 issue, we launched a new series called *Concrete Bridge Technology*. This series cuts across design, detailing, and construction questions that are often on practitioners' minds. Many of us who have been around the industry for some time take many aspects of design and construction for granted because we have grown up with them. Yet, anybody coming into the industry today has little idea about their history or background. We hope this series will begin to fill this void.

To increase the usefulness of the magazine to the academic world, we added a series called *A Professor's Perspective* in Winter 2015. This series

focuses on addressing topics related to creating the next generation of concrete bridge engineers. The articles are aimed at both teaching concrete bridge design and introducing students to their career as a practicing bridge engineer.

In the first edition of *ASPIRE*, there were six series. Now, we have a total of 19, although every series does not appear in every issue.

In the first edition of *ASPIRE*, there were six series. Now we have a total of 19.

To date, we have featured articles from 46 states. If your state is not one of them, we would like to hear from you at info@aspirebridge.org.

What is Next?

If you have read this far, you will know that *ASPIRE* has changed incrementally to meet the needs of its readers. No doubt this will continue into the future but the overall mission of delivering both inspirational and practical information about all types of concrete bridges will remain.

During the life of *ASPIRE*, changes have taken place in the concrete bridge industry. *ASPIRE* has reported on the longest span segmental box-girder bridge in the United States; the use of curved, precast, prestressed

concrete U-beam bridges; the practical application of ultra-high-performance concrete as a grouting material for joints; and the first extradosed cable-stayed bridge in the United States to name a few. No doubt that the next 10 years will provide many new projects and new ideas for *ASPIRE* to report.

Acknowledgements

The accomplishments of *ASPIRE* would not have been possible without the enthusiasm and drive of the initial Executive Editor, John Dick; the new ideas and leadership brought in by William Nickas, the current editor-in-chief; the original layout designs by Leader Graphic Design; the contributions of our regular authors, Frederick Gottemoeller and Dr. Dennis Mertz; the participation of the Federal Highway Administration; the willingness of the Precast/Prestressed Concrete Institute to accept the financial risk as the publisher; the support of the other associations whose logos now appear on page 2; our advertisers; the production staff over the 10-year period and, finally, the many authors, who have contributed articles. With your help, *ASPIRE* has become a truly industry-wide publication. 

Dr. Henry G. Russell is an engineering consultant who has been involved with the application of concrete in bridges for 40 years. He served as the managing technical editor of ASPIRE™ from the first issue in 2007 through the Fall issue of 2014.

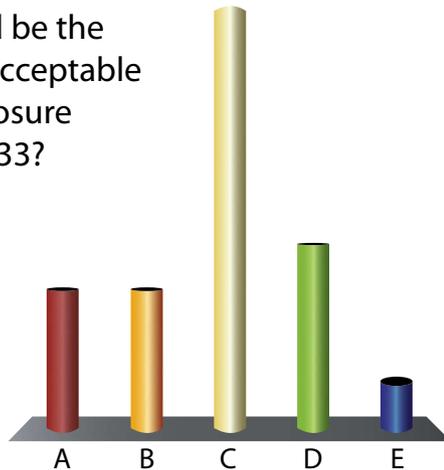
The Value of ABC

A department of transportation perspective from Vermont

by Jennifer Fitch, Vermont Agency of Transportation

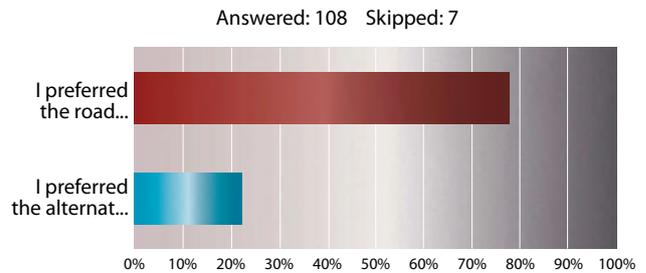
What would be the maximum acceptable length of closure for Bridge #33?

- A. 5 days
- B. 1 week
- C. 10 days
- D. 2 weeks
- E. 4 weeks



According to a Vermont Agency of Transportation survey, 45% of respondents found a 10-day closure acceptable. All Photos and Figures: Vermont Agency of Transportation.

How would you rate your level of satisfaction with the road closure compared to alternating one-way traffic following the bridge closure period?



Survey respondents overwhelmingly preferred short, total road closures to longer, alternating one-way closures.

The value and benefits of accelerated bridge construction (ABC) are often easier to distinguish and realize in urban environments characterized by high traffic volumes, congestion, and greater roadway densities. In these areas, ABC dramatically reduces work-zone, road-user costs. This coupled with other project costs including right-of-way acquisition (ROW), project administration, environmental permitting, and utility relocation, or lack thereof, often results in lower project costs making it an easy sell to lawmakers, the public, and other stakeholders.

Moreover, at a time when many of our urban highways are over capacity and customers have come to expect a reliable transportation network, building and maintaining support for efficiently preserving our highway assets can be easier with ABC, especially when detour routes are short. However, in rural states like Vermont, it can be harder to justify the value of ABC where daily traffic volumes and associated roadway user costs tend to be low. In addition, roadway networks are scarce, which results in lengthy detours, making it difficult to garner public support.

So what is the value of ABC and how should its value be measured? Like other states, many of the typical benefits hold true regardless of geography. For example, by closing a road rather than installing a temporary bridge, impacts to right-of-way, environmental resources, and utilities are reduced or eliminated altogether, facilitating expedited project delivery and rapid replacement of deteriorating infrastructure.

With Vermont's lengthy environmental permitting and ROW processes, the use of ABC substantially reduces the time it takes to deliver bridge rehabilitation and replacement projects, ultimately lowering design costs and reducing resource demands. Short-term road closures also improve safety for motorists and construction workers alike by routing traffic around rather than through the work zone.

Vermont Agency of Transportation's (VTrans') mission, like many other transportation agencies, includes providing for the safe movement of people and goods. VTrans' Structures Section recently adopted a general

rule of considering road closures as the preferred option for maintaining traffic unless deemed impractical during the project initiation phase. While not always obvious, short-term road closures also minimize impacts to the traveling public and commerce by significantly reducing on-site construction duration. Results from a public survey following three consecutive rapid bridge replacement projects on VT 73 in 2014 showed that 82% of respondents felt very satisfied with ABC even though the detour length was 51 miles over mountainous terrain.

In 2012, VTrans created the Accelerated Bridge Program (ABP). Since its inception, VTrans has reliably expedited project delivery and reaped many of the common benefits attributed to ABC. This success has added unanticipated value by becoming ingrained in our organizational culture promoting innovation throughout all phases of project delivery. In addition, the ABP has gained significant support from local politicians and, with this support, has been able to pass legislation that further enables and promotes the

program. Finally, VTrans has found that ABC adds substantial value to legacy projects that were once shelved due to public opposition to conventional construction.

Expediting Project Delivery

At a time of increased federal funding associated with American Recovery and Reinvestment Act (ARRA), along with an aging bridge population, VTrans examined various strategies to expedite the delivery of bridge projects. However, the narrow widths common to Vermont's workhorse bridges ruled out phased construction. This limitation, coupled with Vermont's lengthy ROW and environmental permitting processes required for temporary bridges, made it difficult to achieve the goal of expediting project delivery. In the past, ABC with short-term road closures was only used when all other alternatives were discounted. However, VTrans quickly came to realize that the project development process could be streamlined by using ABC.

In 2012, VTrans reorganized, creating the project initiation and innovation team (PIIT) and ABP. The PIIT was formed to ensure an efficient, consistent, and programmatic approach to identifying the best alternative for rehabilitating and replacing deteriorated bridges and culverts. This process considers the needs of the bridge; maintenance of traffic options, construction practices, and contracting methods; along with an emphasis on the context of the corridor and community involvement. Rather than looking at ABC and short-term closures as the last choice, these methods are examined alongside more conventional construction practices and only discarded if found impractical.

To ensure the successful implementation of ABC on a statewide basis, the ABP was established to specialize in expedited project delivery using prefabricated bridge elements and systems (PBES) and short-term road closures. By minimizing project impacts, VTrans has been able to reduce the project development phase from 60 months down to just 24 months, allowing VTrans to respond quickly to increases in funding, emergency bridge replacement projects, and bridge inventory performance measures. The ABP could not have come to fruition

at a better time. In August 2011, Tropical Storm Irene pummeled the slopes and valleys of Vermont, severely damaging more than 500 miles of state roads and 200 bridges, which isolated 13 communities.¹ Shortly after the initial response to repairing Vermont's transportation network, the ABP tapped into lessons learned by delivering all 15 emergency relief projects within 12 to 24 months. In addition, resource demands have been greatly reduced or eliminated allowing precious resources to be allocated to larger, more complex projects. This is something that is necessary at a time when state agencies are asked to do more with less.

Creating a Culture that Values Innovation

Like most large organizations, it is often difficult to innovate because standard operating procedures and associated habits are hard to change. The same holds true for roadway network users. At the onset of the ABP, team members met with stakeholders from around the state to demonstrate the value of ABC and PBES and garner support for the program. These forums provided an opportunity to vet best implementation practices and discuss concerns from the public, emergency responders, and contractors. This early and continued collaboration created invaluable partnerships and a means for stakeholders to become invested in the program.

In addition, project managers (PMs) within the ABP were given a great deal of latitude and were encouraged to explore strategies for streamlining the project delivery process. This promoted creativity and calculated risk taking. Since the initial projects stemmed from Tropical Storm Irene, the ABP had support at the highest levels within VTrans to meet or exceed the time requirements associated with emergency-response funding along with a heightened urgency to restore the transportation network.

As these project progressed, members of the ABP team met regularly to share lessons learned and to recommend strategies to incorporate into standard operating procedures. This included determining concurrent development activities, how to effectively and efficiently coordinate with resource

Garnering Political Capitol

As word began to spread about the Accelerated Bridge Program (ABP), Vermont legislators became increasingly interested to learn more about rapid bridge replacement projects. Staff from the ABP were invited to provide an overview of the program to the House and Senate Transportation Committees. Committee members were impressed with the programmatic use of accelerated bridge construction (ABC) and reduced project impacts.

During these initial meetings, transportation committees brainstormed ideas to promote ABC on a statewide basis. These efforts ultimately led to the enactment of Act 153 in 2012, which reduces a town's share of local project costs by 50% if the town elects to close the road rather than install a temporary bridge. This provides a considerable financial incentive for towns to favor ABC. Ultimately, this legislation has propelled the use of ABC with 20 towns electing to take advantage of Act 153. Once towns become accustomed to short-term road closures to quickly deliver projects with minimal impacts, they are receptive to supporting ABC on state highway projects.

groups, best practices for public engagement, and standardizing plan sets and specifications. By creating a more inclusive and collaborative process, teams working on ABP projects became invigorated and excited to take a fresh look at modifying standard procedures which cultivated pride, ownership, and innovation.

As the first projects went out to construction, communities were hesitant to accept short-term road closures. Most residents, business owners, and emergency services were skeptical of ABC. To alleviate concerns, PMs worked closely with affected communities providing real time information and assurance that short-term road closures would actually reduce traffic impacts. In addition, most contracts were incentivized to open the road early, providing greater assurance of successful projects. As the first projects

were completed and roads reopened, communities began to embrace ABC with many towns holding celebrations. With these initial victories, the ABP gained significant momentum.

Partnering with Local Communities

Public involvement is often considered an impediment to project delivery. The public and other customers often have differing opinions and developing consensus can be difficult. However, investing in early and continued public involvement is essential to achieving buy-in and ongoing support. VTrans has found that public endorsement for the preferred alternative during the project initiation phase removes several barriers to delivering the project in construction and increases overall public satisfaction with the final product.

By its very nature, ABC with short-term road closures requires heightened public involvement throughout the project delivery process. For example, it's vital to ensure that affected communities agree in advance to a short-term road closure to curtail public opposition during design and construction. Communities must also be engaged to determine the optimum timing and duration of the closure to mitigate impacts to community events, local businesses, and emergency services. As construction begins, project outreach is essential to keep roadway users and other stakeholders informed prior to, during, and following the short-term closure to plan travel accordingly.

Public involvement and outreach has proven highly successful in the deployment of ABC and achieving public satisfaction.

Public involvement and outreach has proven highly successful in the deployment of ABC and achieving public satisfaction. On average, over 80% of all respondents have been very satisfied with ABC, even in communities that were initially opposed to this approach to project delivery.

Using ABC to Deliver Legacy Projects



Middlebury Sand Hill Bridge legacy project in 2014.

Several projects within the Vermont Agency of Transportation had been on the books since the early 1980s. Many of these projects were put on hold because of public opposition due to impacts from traditional construction methods. Often, other conventional solutions were proposed, only to be met with more disapproval due to community concerns over project impacts and traffic management strategies. This created significant inefficiencies including lengthy schedule delays and increased costs for these legacy projects.

With the establishment of the Accelerated Bridge Program in 2012, all legacy projects were reexamined to determine if accelerated bridge construction (ABC) was the right solution to revitalize these projects and in many cases, it was the only viable solution. After years of projects at a standstill, this innovative approach was embraced by the affected communities and other stakeholders.

The Middlebury Sand Hill Bridge is a prime example of a legacy project. The historic 49-ft-long arch structure built in 1924 was programmed for replacement in 1983. A community landmark in a recreational area, the site was surrounded by constraints including archeologically significant mill sites, a recreational swimming hole, and aerial utilities. Phased construction was not an option given the bridge type and inadequate bridge width. As a result, the original scope included a temporary bridge adjacent to the existing structure that posed significant impacts and public hardship. Even widening the bridge to meet state standards was contentious.

All of these factors caused the project to come to a halt. A solution that minimized project impacts and met historic requirements seemed impossible until a short-term road closure was considered. This strategy was much more palatable to the community and rejuvenated the project again after 28 years. To shorten construction, engineers designed an arch-like structure utilizing prefabricated bridge components. With this ABC solution, the project was delivered in just 3 years highlighting the successful use of innovation to remove impediments to delivering projects. The new arch was constructed in 42 days, 3 days short of the allowable 45-day closure period.

Three Years of Proven Performance

Since implementation in 2012, the ABP has delivered 28 projects totaling \$71.3 million with another 17 projects under development. The program has gained significant momentum and has proven successful at expediting project delivery by reducing the standard design duration from 60 months for conventional projects down to 24 months. Due to these achievements, the program has also received the support of Vermont's legislative branch which enacted Act 153 that reduces the town share of costs on local projects by 50% if the town chooses to close the road versus installing a temporary bridge. The ABP has also been used to replace several legacy bridge projects programmed since the 1980s. Much of this success is attributed to partnering with local communities.

Reference

1. Vermont Agency of Natural Resources. 2012. "Tropical Storm Irene," Vermont Agency of Natural Resources. October. <accessed January 30, 2016. <http://www.anr.state.vt.us/anr/climatechange/irenebythenumbers.html>>.

Jennifer Fitch is a project manager with the Vermont Agency of Transportation in Montpelier.

EDITOR'S NOTE

This paper was originally submitted and presented at the 2015 National ABC Conference.



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Fort Goff Creek Bridge

A project to restore fish passage



by Dorie E. Mellon, California Department of Transportation

Fort Goff Creek Bridge. All Photos: Caltrans.

During the construction of California's highway system, hundreds of culverts were installed to allow creeks to flow under roads. Many of these culverts acted as barriers to migrating fish, effectively cutting off upstream access. The Fort Goff Creek Bridge was proposed in response to the commitment by the California Department of Transportation (Caltrans) to restore fish passage in California. California Senate Bill 857 (Kehoe, Chapter 589, Statutes of 2006) and

Article 3.5 of Chapter 1 of Division 2 of the California Streets and Highways Code require the removal of barriers to fish passage where highways cross anadromous fish-bearing streams. Anadromous fish are migratory fish that breed in fresh water and spend a portion of their lives in the ocean.

The barrier caused by the culvert carrying the water of Fort Goff Creek under State Route 96 was identified by Caltrans as a top-priority fish-passage remediation project. The streambed restoration project replaced the 15-ft-diameter corrugated metal pipe culvert with the Fort Goff Creek Bridge, a 60-ft-long, single-span precast concrete structure. Construction of the bridge allowed for the channel section and the stream bed beneath the highway to be restored to a natural

state, providing unimpaired passage for anadromous fish. Removal of the barrier opened miles of habitat for the migration, spawning, and rearing of threatened and endangered species including steelhead trout and Chinook and Coho salmon.

Structure Selection

The project, in a remote part of Northern California along the Klamath River in Siskiyou County, presented a number of challenges to conventional cast-in-place concrete construction. The site is located in a severe climate area where freezing and thawing cycles and heavy salting occur frequently, and tire chain use is common. These conditions require special attention to the longevity of the bridge deck and the structure in general. The nearest ready-mixed concrete batch plant is located approximately 90 minutes away, which created a situation where cast-in-place concrete quality could be compromised by traffic delays. Traffic



The existing culvert blocked fish passage due to the slope of the culvert and the vertical drop at the inlet and outlet.

profile

FORT GOFF CREEK BRIDGE / SISKIYOU COUNTY, CALIFORNIA

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

PRIME CONTRACTOR: Stewart Engineering, Redding, Calif.

PRECASTER: KIE-CON Inc., Antioch, Calif.—a PCI-certified producer

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

and environmental constraints called for one season construction and minimized impacts to the stream bed and surrounding areas. In addition, this project had multiple funding sources and many stakeholders. Caltrans needed a bridge type that would address the interests of all parties involved.

Multiple structure types were evaluated during the planning phase of the project. A prefabricated bridge element system (PBES) was identified as the preferred construction method for the 36-ft-wide, 60-ft-long, single-span structure. The drivers for accelerated bridge construction (ABC) and use of a PBES included improved quality of concrete elements, reduced environmental impacts, and the single construction season restriction.

Structure Design

The PBES structure design utilized nine adjacent 2-ft 1-in.-deep, 4-ft 1-in.-wide precast, prestressed voided concrete slabs; precast concrete abutments; precast concrete wing walls; and prefabricated steel barrier rail (California ST-70 bridge rail). To further enhance durability, epoxy-coated steel reinforcing bars were used in the voided slabs and for the top layers of reinforcement in the abutment back wall and precast concrete wingwalls. The riding surface was provided by a 1½-in.-thick polyester concrete overlay. Concerns over constructability issues, associated schedule delays, and other challenges



of implementing innovative methods were addressed through the use of the *ABC Toolkit*¹ and funding from the Strategic Highway Research Program 2 (SHRP2) Implementation Assistance Funds for Innovative Bridge Designs for Rapid Renewal. The *ABC Toolkit*, a SHRP2 product, “provides a series of design and construction concepts for prefabricated elements and their connections.” Architectural treatment was provided on the precast concrete wingwalls and barrier end walls through formliners and on-site concrete staining.

Construction

The construction contract was awarded in the spring of 2014 by the design-bid-build/low-bidder method and detour construction began on May 30, 2014. Single-lane signalized traffic was carried on a detour over a temporary culvert for the duration of the project.

Precast concrete abutments were founded on a single row of 30-in.-diameter, cast-in-drilled-hole (CIDH) piles with permanent casing. Due to difficulties with drilling and drilling equipment, the pile installation was completed in early September. The precast concrete seat-type abutments were erected in segments to keep element weights below 100 kips for ease of transportation and placement. Each abutment consisted of three segments weighing 85 kips each. A 275-ton crane was used by the contractor to place the abutment elements in 2 days. Large voids formed with corrugated metal pipe fit over reinforcement cages extending from the piles. The abutment elements were connected by grouted keyways using 14 ksi grout and post-tensioning with 1⅜-in.-diameter high-strength tie rods

Reinforcement in the skewed section of the girder, rail hardware, prestressing ducts, and voids caused significant congestion at the voided slab girder ends. Future designs will aim to reduce congestion and improve constructability.



Preassembly of abutment elements at the fabricating yard ensured fit up with piles and tie rod ducts in the field.

with a post-tensioning force of 100 kips per tie rod. Abutment voids were filled with 6 ksi grout.

Once the abutment grout had reached a strength of 2.6 ksi, the 65-kip precast concrete voided slabs and 20-kip wing walls were set in a single day. Precast concrete wingwalls were connected to the abutment by closure placements with 4 ksi concrete. The voided slabs were connected to each other by 14 ksi grouted longitudinal keyways (5 ksi was required in 24 hours) and transverse post-tensioning of 1⅜-in.-diameter, high-strength tie rods with a post-tensioning force of 150 kips per tie rod.

A 1½-in.-thick riding surface of polyester concrete was placed on the precast concrete superstructure in mid-October followed by the barrier rail. By embedding anchorages in the precast concrete curb of the exterior girders, the barrier rail was installed in a matter of hours. Work was completed and the traffic was shifted to the permanent structure on November 12, 2014.

Lessons Learned

Best practices from the *ABC Toolkit* incorporated into the Fort Goff Creek Bridge project included

- using a single row of piles under the precast concrete abutment,
- using repeatable elements,
- keeping pick weights under 100 kips,
- pre-assembling substructure elements prior to shipping, and
- incorporating fabrication and erection tolerances in the plans and special provisions.

CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 60-ft-long, single-span, precast concrete voided slab bridge with precast concrete abutments and wingwalls

STRUCTURAL COMPONENTS: Nine precast/prestressed concrete voided slab girders, six precast concrete seat-type abutment segments, four precast concrete wingwalls, and 30-in.-diameter cast-in-drilled-hole piling with rock socket

BRIDGE CONSTRUCTION COST: \$1,400,303 (\$660/ft²)

AWARDS: 2015 PCI Design Awards Honorable Mention: Bridge with a Main Span Up to 75 Feet



Precast concrete elements at the jobsite ready for quick assembly.



A cement slurry provided an excellent leveling pad for quick and accurate placement of 85-kip abutment segments.



Precast concrete elements are connected by grouted keyways, post-tensioned tie rods, and closure placements.

Other items added for ease of implementation were

- using a cement slurry as a leveling pad for the abutment stems,
- using prefabricated rail,
- including the rail curb in the precast exterior slab elements,
- including a construction sequence on the plans, and
- providing extra overlay thickness to accommodate differential camber and fabrication tolerances.

An unexpected benefit of PBES construction was the mitigation of a 63-day schedule overrun due to foundation construction problems. Pile installation poses a significant schedule

risk on any project, especially under conditions of wet and difficult drilling. The schedule delays introduced by the CIDH piling on the Fort Goff Creek Bridge were effectively offset by the rapid assembly of the PBES structure (71 days for foundation construction versus 23 days for bridge construction). The use of precast concrete elements removed the threat of the project extending into a second season, thereby avoiding additional cost, extended traffic delays, and a significant increase in environmental impacts.

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Improved Project Delivery

The Fort Goff Creek Bridge project provided several lessons learned that will allow Caltrans to improve ABC and PBES project delivery going forward. Engineers recognized several opportunities to improve the shop drawing review process, including the development of a review checklist, a longer review time to provide adequate time to review the increased number of shop plans, and concurrent shop plan submittal to identify conflicts between prefabricated components.

Going forward, Caltrans is considering the requirement of building information modelling (BIM) of precast concrete elements and connections to avoid reinforcement congestion and to improve constructability. BIM would be particularly helpful in identifying geometric complications introduced by skews, cross slopes, and horizontal and vertical curves. Lessons learned also include increasing resources for materials inspections and enforcement of quality control/quality assurance practices. ABC projects should be staffed with individuals that embrace

Fast-track Permits for ABC

Caltrans has identified over 500 fish passage barriers that must be addressed to provide unrestricted passage of anadromous fish. Because of the success and subsequent publicity about this fish passage project, our permitting partners (National Marine Fisheries Service and California Fish and Wildlife) would like to pursue a programmatic permitting process for accelerated bridge construction (ABC) structures that has the potential of reducing the permitting process from between 6 to 12 months to 30 days. This streamlining of the permitting process will yield big savings in time and support costs.

innovation and continue outreach efforts to gain support for ABC construction. These should include Caltrans staff, as well as external partners from the construction industry, funding sources, and permitting agencies.

ABC and PBES construction successfully delivered a one-season solution for the Fort Goff Creek Bridge project. This type of construction was well received by the contractor and Caltrans construction staff. Project managers in northern California have identified several future projects that would benefit from a similar approach and envision widespread application in fish passage projects statewide. Caltrans continues to pursue ABC and PBES on a larger scale in order to effectively mainstream ABC in California.

References

1. Transportation Research Board (TRB). 2013. *Innovative Bridge Designs for Rapid Renewal ABC Toolkit*, SHRP 2 Report S2-R04-RR-2.

Dorie E. Mellon is a senior bridge engineer with Structure Policy and Innovation, Division of Engineering Services for the California Department of Transportation in Sacramento.

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PROJECT

Petaluma River Bridge Replacement on US 101

Project aims to lessen traffic congestion north of San Francisco, California

by Walt LaFranchi, AECOM

Completed northbound side of the Petaluma River Bridge. Photo: Caltrans.

This bridge replacement project will ultimately reduce traffic congestion in the infamous bottleneck area of US 101 north of San Francisco, Calif., known locally as the Marin Sonoma Narrows (MSN). In this area, US 101 narrows to a four-lane expressway with multiple access points from neighboring properties. The proposed MSN project will improve a 16.1-mile-long segment of this congested area with improvements that include constructing high-occupancy vehicle (HOV) facilities, widening and realigning portions of the highway, constructing new interchanges, upgrading drainage systems, and constructing new frontage roads and bikeways. The Petaluma River Bridge Replacement project is one of the key high-profile projects in this segment.

Bridge Setting

The existing bridge consists of a nine-span, 886-ft-long twin structure that utilized a cast-in-place reinforced concrete box-girder bridge with a drop-in precast concrete girder span over the navigable Petaluma River. The existing twin structures were each

6 ft deep, 32 ft-4½ in. wide, and were supported on single column bents. A former rock quarry lies south of the bridge, allowing the existing structure foundation to be supported on spread footings. However, worsening soil conditions at the northern end of the existing bridge required the use of driven concrete piles. All supports were on an approximately 36-degree skew. The existing bridge had a minimum vertical clearance of approximately 70 ft over the mean high-water level and a horizontal clearance requirement of 100 ft from the United States Coast Guard (USCG). Seismicity for the site has an anticipated peak acceleration response spectrum of 1.4g from an earthquake with a magnitude of 7.1 and 0.6g peak rock acceleration.

Bridge Type Selection

One goal for the Petaluma River Bridge Replacement project was to replace the existing twin structures with one single structure that is 117 ft wide and 907 ft long. The replacement bridge accommodates three lanes of traffic

in each direction plus standard-width shoulders. The number of spans is reduced to five with a bridge span layout of 113, 180, 212.5, 212.5, and 169 ft.

Right-of-way restrictions on either side of the bridge, design speed requirements of the freeway, line of sight requirements for vehicles (limited height to raise the highway), and marine vessel vertical clearance requirements restricted the location of the replacement bridge to be in basically the same location as the existing bridge. Therefore, one of the main challenges of this project was determining how to stage the construction of the new bridge.

During bridge-type selection, it was anticipated that three stages of construction would be needed, with the first stage of the replacement bridge (both superstructure and substructure) to be constructed between the existing twin structures. The existing northbound bridge could then be removed and construction of the new northbound side of the bridge (stage two—both superstructure and substructure)

profile

PETALUMA RIVER BRIDGE REPLACEMENT ON US 101 / PETALUMA, CALIFORNIA

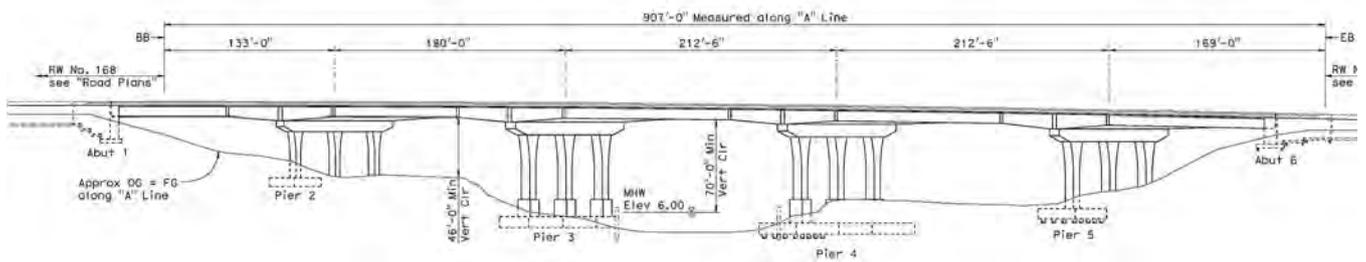
BRIDGE DESIGN ENGINEER: AECOM, Sacramento, Calif.

PRIME CONTRACTOR: Ghilotti Bros. Inc., San Rafael, Calif. (prime contractor) and C. C. Myers Inc., Rancho Cordova, Calif. (bridge contractor)—a joint venture

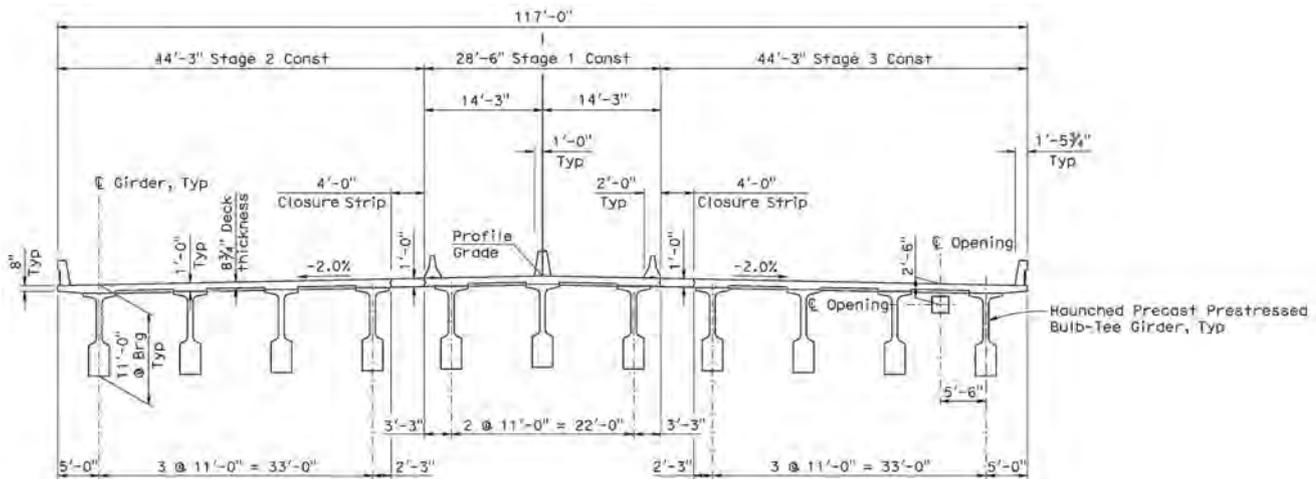
PRECASTER: Con-Fab California Corporation, Lathrop, Calif.—a PCI-certified producer

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

ERECTION CONTRACTOR: Bigge Crane & Rigging, Stockton, Calif.



Elevation showing the bridge spans and configuration. Drawing: AECOM.



Typical section at pier. Drawing: AECOM.

could begin. A similar staging would occur for the southbound side of the bridge. All of this construction would take place in very restricted areas for access and working room. However, the contractor was able to develop a construction scheme that allowed all of the replacement piers to be constructed in their entirety (without staging) under the existing twin structures, even with very limited head room.

Various superstructure types were considered during the type selection process for this bridge. The two types of bridges considered for final design were

- a cast-in-place, prestressed concrete box-girder bridge with precast concrete bulb-tee girders over the river, and
- a spliced, precast concrete haunched bulb-tee girder bridge.

The first thought was to utilize a similar structure type as the existing bridge, that is, a cast-in-place, box-girder bridge with a span of precast concrete girders over the river. The span of precast concrete girders was required because the use of falsework would be problematic for this span. Although this type of bridge would have been similar to the existing bridge and the estimated construction cost was the least of the alternatives at \$27,786,000, it was not selected.

The bulb-tee girder option used 81-ft-long, haunched precast concrete girder segments at each pier that were spliced with constant-depth girders

Contractor was able to construct entire pier under existing twin bridges. Photo: Caltrans.

to complete each span. The constant depth girders were 7 ft deep and the haunched pier segments varied in depth from 7 to 10 ft. There were 99 precast concrete segments in the superstructure. The longest constant-depth segments weighed 79.5 tons each and the variable-depth pier segments weighed 87 tons each. The overall staging of the construction of the spliced-girder option would be



CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

SPONSORING AGENCY: Sonoma County Transportation Authority, Santa Rosa, Calif.

BRIDGE DESCRIPTION: A five-span, 907-ft-long, 117-ft-wide bridge with haunched, spliced, precast, prestressed concrete girders with main spans of 212 ft 6 in.

STRUCTURAL COMPONENTS: Ninety-nine precast concrete bulb-tee segments including 44 haunched pier segments and fifty-five 7-ft-deep constant depth segments; an 8 3/4-in.-thick composite deck; 7000 linear feet of 36-in.-diameter, cast-in-drilled-hole concrete piles

BRIDGE CONSTRUCTION COST: \$25.5 million (\$243/ft²)



Pier girder segment in precast concrete plant. Photo: Caltrans.

similar to the concept for the drop-in span of the box-girder option. The proposed construction sequence for each stage of construction for the spliced-girder option was as follows:

- Erect the haunched pier segments over piers 2, 3, 4, and 5 and stabilize the segments with temporary falsework bents in the back spans
- Erect end-span segments in spans 1 and 5 between the abutments and temporary falsework bents
- Erect span 2 and 4 segments with strongbacks on one end of the girder resting on pier segments and the other end supported by temporary falsework bents
- Erect the span 3 segment over the Petaluma River with strongbacks on both ends resting on pier segments
- Place concrete for the girder splices, then post-tension the girders
- Remove temporary falsework bents and place concrete for the deck
- Perform final post-tensioning, then place barriers and joint seals

Even though the engineer's estimate of construction cost with this type selection was slightly higher at \$28,142,000, using this method of construction eliminated all the falsework in the river area, provided a single continuous structure type, and reduced the construction schedule, which lessened the impact on US 101 traffic. It also allowed Caltrans to gain more experience with long-span precast concrete girders.

Design Challenges

The bridge deck was supported by 11 lines of haunched, precast, prestressed concrete bulb-tee girder segments spaced 11 ft apart. The bridge was constructed in three stages. Design challenges included the high skew, the long continuous bridge length, and the staged construction. The girder segments were pretensioned at the fabrication yard utilizing 0.6-in.- diameter strand on a straight alignment with debonding. Post-tensioning of the girders in the field used five tendons (in 3½-in.-diameter ducts) in the webs and two tendons (in 1⅞-in.-diameter ducts) in the each flange for the span segments; for the haunched segment an additional tendon was utilized in the bottom flange (in a 3⅞-in.-diameter duct). Due to the length of the tendon paths, two-end stressing was utilized for the phases of post-tensioning. The first phase was performed after the diaphragms at the abutments and piers and the girder splices were placed and cured. The second phase was performed after the intermediate diaphragms and deck slab was placed. The third phase was performed on the pier diaphragms in the transverse direction. Other design challenges included time-dependent analysis and deflection control to ensure compatibility between stages.

To lighten the cap weight and reduce the seismic loads on the bridge, the dropped bent caps were originally designed with rectangular voids. The contractor requested that round voids be used for easier construction and better concrete placement. A wave pattern with fractured rib texture, similar to that used on the concrete bridge barriers for the US 101 corridor in this segment of the highway, was utilized on the side faces of the pier caps. Columns also had the fractured rib texture.

Three of the piers were supported by three, 8 by 8-ft columns with 24-ft-high,



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one-way column flares with an 8 by 10 ft in cross section. Columns were fixed at the top and bottom at all pier locations except for the southerly pier. At the base of the columns adjacent to the river, an enlarged section (12 by 12 ft) was utilized for the additional strength needed for the seismic and barge-impact loads. The most southerly pier of the bridge was much shorter than the other piers. Thus, due to high thermal, creep, and shrinkage loads, a reduced cross section of 6 by 6 ft and smaller column flares were utilized in conjunction with a sliding bearing at the top of the pier cap.

During design, a fender replacement system study was performed. Due to the nature of the varying soil subsurface and the resulting significant costs needed for replacing the existing fender systems for this site, it was decided to not utilize a fender system. Instead, marine vessel collision loads were designed to transfer directly into the substructure of the piers on each side of the river. Working with the USCG and barge users on the river, the design barge used was 260 by 55 by 15 ft with a bow rake of 30 ft, an empty weight of 750 tons, a loaded weight of 4600 tons, a tug weight of 300 tons (with a maximum tug velocity of 6 knots), and a design impact speed of 11.3 knots resulting in significant lateral design loads applied to the bottom portion of the piers. The resulting footing sizes became large, but instead of three separate footings for the columns at each pier, a continuous strip footing was utilized.

Spread footings were utilized at the south end at abutment 1 and pier 2; 36-in.-diameter, cast-in-drilled-hole concrete piles were utilized at piers 4, 5, and 6; and 14-in.-square precast concrete piles were utilized at abutment 7.

Construction Challenges

Installation of cofferdams on either side of the river was necessary for construction of the replacement bridge and removal of the old bridges. A temporary falsework platform and trestle system was utilized to remove the existing bridges and construct the new bridge.

All spans utilized two girder splices except the end spans that utilized only one splice. Vertical support for the girder loads at the splice locations was provided by temporary falsework where feasible,

such as the end spans, span 2 adjacent to Petaluma Boulevard North, and one of the splices in span 4. At piers 3 and 4 (adjacent to the river), falsework could only be erected on the land side (the side away from the river) of each pier. Consequently, the contractor installed tie-downs to counter the load of the girders for the span over the river. The tie-downs consisted of 1 $\frac{3}{8}$ -in.-diameter, high-strength threaded rods drilled and bonded 50 ft deep into the ground. Each rod was load tested to a capacity of 90 tons for pull-out load verification. For stage 1 construction in the median of US 101, two tie-downs were required on each side of the river (four total); for stages 2 and 3 (northbound/southbound portions) three tie-downs were used on each side of the river (six total).

Using couplers, each threaded rod was extended up to the back side (away from the river) of the haunched girders at piers 3 and 4. At the girder level, the extended threaded rods connected via a custom made brace to a W14x145 strongback placed transversely across all girders in that stage. This arrangement provided enough capacity to counter the load of the girders in the span over the river while providing the ability to place the girders during the allowable lane closure hours. Strongbacks on each girder were utilized in the two splices in the span over the river (span 3) and one splice in span 4.

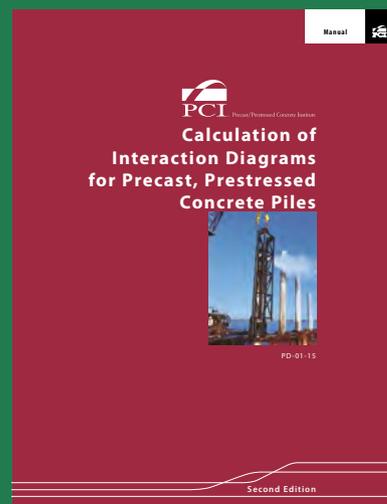
The contractor utilized a 300-ton crane for the placement of the precast concrete girder segments. Girders for the span over the river required approximately 85% of the crane's lifting capacity.

To support the crane and girder weight adjacent to the river, the contractor constructed temporary crane pads at each quadrant. The reinforced concrete pads were 55 by 85 by 2 ft and were thickened to 3 ft at each of the pile locations. The sixty-five, 200-ton piles for each temporary pad were driven 60 ft deep at pier 4 and 40 ft deep at pier 3. 

Walt LaFranchi is the northern California transportation group manager for AECOM in Sacramento, Calif.

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PROJECT

SR 520 Evergreen Point Floating Bridge Low-Rise Superstructure

Precast concrete, ribbed-slab segments

by David B. Birrcher and Christopher M. Hall, International Bridge Technologies Inc.

Aerial view of state route (SR) 520 Evergreen Point Floating Bridge Low-Rise Superstructure under construction. Photo: KGM.

The state route (SR) 520 Evergreen Point Floating Bridge and Landings project is an 8643-ft-long project crossing Lake Washington near Seattle, Wash. The floating bridge portion—the Evergreen Point Floating Bridge—is 7710 ft long, making it the longest floating bridge in the world. It replaces the old SR 520 floating bridge that was opened to traffic in 1963 and that currently holds the record as the longest floating bridge. The Washington State Department of Transportation determined that the old bridge needed to be replaced to improve traffic congestion, maintenance access, and bridge performance under extreme events such as windstorms.

Structure Types

The project consists of four different structure types supported on floating concrete pontoons or traditional fixed

foundations. At the eastern end of the project, a concrete, cast-in-place segmental twin box-girder bridge is supported on spread footings. The twin box-girder bridge is 627-ft-long with a main span of 320 ft. A 190-ft-long transition span connects the box-girder bridge to the floating bridge. At the western end of the project, another 190-ft-long transition span connects the floating bridge to the west-approach structure. The west approach is part of a different contract. The transition spans and their pinned connections accommodate differential displacements and the associated rotations between the floating bridge and the fixed approach structures due to changes in the level of Lake Washington.

The support structure for the Evergreen Point Floating Bridge consists of 77 concrete pontoons joined together

and anchored to the lake bed with large steel cables. For 1150 ft at the east end, and for 880 ft at the west end, reinforced concrete columns and bent caps are rigidly attached to the pontoons. They support simple-span, prestressed concrete girders with an 8-in.-thick, cast-in-place concrete deck. The typical span is 90 ft. These two regions of the floating bridge are referred to as the “high-rises.” The east high-rise accommodates a 5% grade; the west high-rise accommodates a 3% grade.

Between the eastern and western high-rise regions is a 5580-ft-long “low-rise” portion of the project. The low-rise consists of a precast concrete, segmental, ribbed-slab superstructure supported on circular columns that are rigidly connected to the pontoons. The low-rise has a straight plan alignment

profile

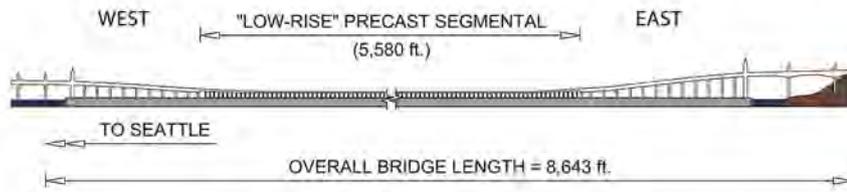
SR 520 EVERGREEN POINT FLOATING BRIDGE LOW-RISE SUPERSTRUCTURE / SEATTLE AND MEDINA, WASHINGTON

BRIDGE DESIGN ENGINEER: International Bridge Technologies Inc., San Diego, Calif.

PRIME CONTRACTOR: Kiewit, General Construction, Manson Construction (KGM)—a joint venture, Federal Way, Wash.

PRIME CONSULTANT: KPFF and BergerABAM, partners as the prime engineering team, Seattle, Wash.

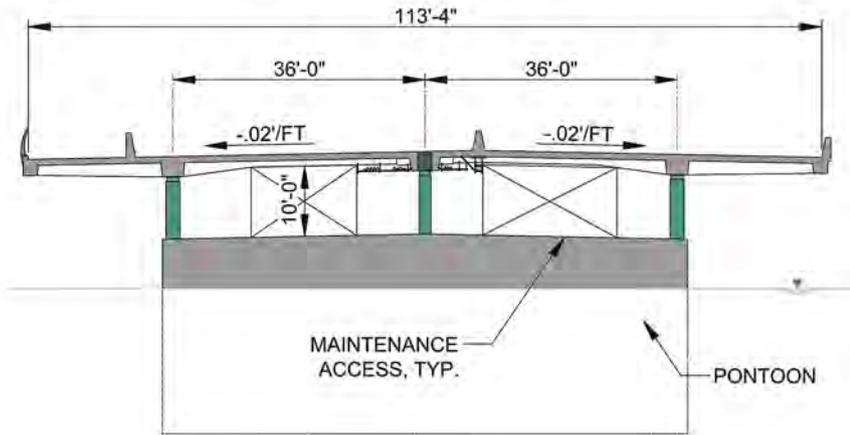
POST-TENSIONING CONTRACTOR: Schwager Davis Inc., San Jose, Calif.



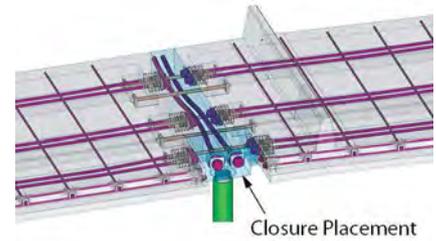
Schematic elevation of the Evergreen Point Floating Bridge and Landings project. Figure: International Bridge Technologies Inc.



Typical precast concrete, ribbed-slab segment showing transverse post-tensioning in ribs. Figure: International Bridge Technologies Inc.



Typical section of low-rise precast concrete ribbed-slab superstructure. Figure: International Bridge Technologies Inc.



Post-tensioning details in segments and longitudinal closure near expansion joint. Figure: International Bridge Technologies Inc.

and a flat profile for the majority of its length. It accommodates a variable grade where it transitions to the high-rise to the east and to the west. The deck has a crown with a $\pm 2\%$ cross slope. The superstructure of the low-rise is the primary focus of this article.

Design Features

The width of the low-rise deck is 113 ft 4 in. to accommodate four traffic lanes, two high-occupancy vehicle lanes, 10- and 4-ft-wide shoulders in each direction, and a 14-ft-wide pedestrian/bike path. Semicircular overlooks called belvederes are positioned adjacent to the pedestrian/bike path at three locations along the low-rise region. The width of the supporting pontoons is

75 ft, which necessitated the use of large cantilever overhangs. Available column locations were further restricted by the cellular structure and ballast requirements of the pontoons.

In addition, 10 ft of vertical clearance between the underside of the bridge and the top of the pontoon was required for maintenance access. The clearance requirement was compounded by a fixed vertical profile that limits the overall height of the low-rise portion of the bridge. The structure is designed to be widened in the future to accommodate two additional mass transit lanes along the centerline of the bridge. Structural modifications to the existing bridge would be limited

to the outer portions of the structure, including supplemental pontoons, supporting frames, and the widened superstructure.

A low-profile, precast concrete segmental ribbed-slab concept was developed to address the project requirements. Variable-depth transverse ribs run the full width of the bridge and are optimized to increase the vertical clearance between the pontoon and the bridge soffit. The ribs are spaced at 7 ft 6 in. and frame into longitudinal beams that are located along each of the three column lines and at each edge of the bridge. A 10-in.-thick slab spans between the transverse ribs and the longitudinal beams.

Three lines of columns are spaced transversely across the width of the pontoon at 36 ft on center.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

BEARING SUPPLIER: Scougal Rubber Corporation, Seattle, Wash.

EXPANSION JOINT SUPPLIER: Mageba USA, San Jose, Calif.

BRIDGE DESCRIPTION: The low-rise portion of this bridge consists of a precast concrete segmental ribbed-slab superstructure on circular columns supported by floating concrete pontoons.

STRUCTURAL COMPONENTS: 776 precast concrete, ribbed-slab segments



Setting of typical 15-ft-long north segment on falsework. Photo: KGM.

Longitudinally, the columns have a 30 ft typical spacing, except near the expansion joints where the spacing is reduced. Steel-reinforced elastomeric bearings are grouted directly between the longitudinal beams and the circular columns. No substructure cross beams are needed. The relative flexibility of the bearings limit the longitudinal and transverse forces that are transferred from the superstructure to the columns and to the pontoons. Further, varying the stiffness of the bearings provided a means to concentrate loads where desired in the pontoons. Twenty percent of the bearings have a steel pintle that positively connects the ribbed-slab segment to the column.

The ribbed-slab superstructure was divided into approximately 56-ft-wide north and south precast concrete segments that were joined together by a 2-ft-wide longitudinal closure strip. To achieve a 360-ft distance between expansion joints, 23 typical segments that were 15 ft long and two expansion-joint segments that were 7 ft 3 in. long were utilized. This arrangement was repeated 14 times. Where the low-rise region transitioned to the high-rise region, the number of typical segments was reduced to achieve smaller distances between expansion joints, which were spaced at 225 ft to the west and 315 ft to the east. In total, 776 precast concrete segments were used. The epoxied joints between segments were located at the quarter-span to reduce stresses at the joints.

The ribbed-slab segments were post-tensioned in both directions. Each transverse rib in the typical 15-ft-long segment had two 11-strand tendons. The ribs in the expansion joint segments had two 12-strand tendons and two 4-strand tendons. Across the longitudinal closure strip, two 1¾-in.-diameter post-tensioning bars were stressed at each transverse rib.

Longitudinal tendons ran the entire length between expansion joints (typically 360 ft). Sixteen four-strand tendons with a straight profile were distributed within the 10-in.-thick slab. In the beams running above the outer column lines, two 25-strand tendons with a variable profile were provided. In the beam running above the center column line, two 27-strand tendons were provided.

In addition to typical strip-seal expansion joints, steel beams were positioned across the joint to provide displacement and rotational continuity. A steel beam and saddle bearing assembly that permitted longitudinal movement was designed in the cantilever overhangs to link vertical displacements. At the centerline of the bridge, a steel beam was detailed to control transverse displacements across the expansion joint.

At the roadway surface, the segments were detailed with 3 in. of clear cover above epoxy-coated, top-



Epoxy-joining of a typical 15-ft-long north segment. Photo: International Bridge Technologies Inc.

mat reinforcement. A portion of the clear cover (½ in.) was allocated for grinding and texturing. No additional overlay was applied, although the design can accommodate one in the future if needed. The ribbed-slab segment concrete had a 28-day design compressive strength of 6.5 ksi and very low permeability.

Construction

The precast concrete segments were match-cast at a nearby site in Kenmore, Wash. The segments were steam-cured overnight and were advanced to the match-cast position the next morning to achieve a 24-hour casting cycle. One casting bed was used for the north segments, and a second casting bed was used for the south segments. The traffic and pedestrian barriers were cast integrally with the segments, but with a ½-in. gap between the barriers at the segment joints. After match casting, the segments were lifted off the formwork and were post-tensioned transversely. The typical 15-ft-long segments weighed approximately 100 tons.

On site, the pontoons were floated and anchored into position. The columns were cast, and falsework was installed between the column lines. The precast concrete ribbed-slab segments were shipped in by barge from Kenmore and were erected onto the falsework with a large barge-mounted crane. The segments were placed on polytetrafluoroethylene pads on the falsework that allowed them to be easily manipulated. Epoxy was applied to the match-cast joints, and the segments were joined via temporary post-tensioning bars mounted to the



View of completed precast concrete ribbed-slab structure from the top of the pontoon.
Photo: International Bridge Technologies Inc.

top of the deck with temporary steel brackets. The north and south segments were epoxy-joined independently. There were five locations across the 56-ft-wide

segment where the temporary post-tensioning was applied. On a typical setting day, eight precast concrete segments were erected. A maximum of

18 segments were erected in 1 day. All 776 segments were erected within 11½ months.

After the segments were epoxy-joined, reinforcement and post-tensioning was placed within the longitudinal closure strip and concrete for the closure was cast. Transverse post-tensioning bars were stressed across the longitudinal closure strip after the concrete reached sufficient strength. Then, the longitudinal post-tensioning tendons were stressed, and the elastomeric bearings were grouted. After the grout reached sufficient strength, the falsework was removed and the superstructure was self-supporting.

The SR 520 Evergreen Point Floating Bridge is scheduled to open to traffic in April 2016. 

David B. Birrcher is a bridge engineer and Christopher M. Hall is a principal engineer at International Bridge Technologies Inc. in San Diego, Calif.

AESTHETICS COMMENTARY

by Frederick Gottemoeller



It may seem odd to focus a discussion of bridge aesthetics on a structure that will only be seen by the occasional Washington State Department of Transportation maintenance worker. What makes it worthwhile in this case is that the structural innovations pioneered here create a unique and attractive bridge that would not be out of place in any park or urban area. The innovations were obviously inspired by the specialized requirements of the SR 520 Evergreen Point Floating Bridge, but the result is a lightweight and economical structure that would apply to any viaduct situation allowing modest spans and modest vertical clearances, especially where accelerated construction is a goal.

Its economy is based on a repeating precast concrete module that combines the longitudinal spanning element, the transversely spanning element, the deck, and the transverse column brace, all in one precast concrete piece. This module can be manufactured off site and quickly erected. This contrasts with the usual precast concrete bridge where only the longitudinal spanning element (I-girder, bulb tee, and others) is manufactured and the transverse spanning element/column brace (pier cap) and the deck are cast in place in separate, time-consuming field operations.

This manufactured module also supplies the aesthetic benefits. First of all, over most of its width it is thinner than the typical girder/deck combination. This allows more clearance and light below, a lower overall structure, or some combination of the two. The deepening of the transverse ribs at the longitudinal beams creates an element of visual interest and demonstrates the flow of forces in the structure. The elimination of a visible pier cap/column brace eliminates the transverse visual element that restricts longitudinal views underneath a typical viaduct and makes the space below seem much more constricted than it need be. Finally, and perhaps most importantly, the ribs themselves create a pattern on the “ceiling” of the space underneath the viaduct that recalls the coffered ceilings of traditional monumental buildings. One can imagine lighting elements along the longitudinal beams washing the underside of the deck between the ribs. Rather than being feared as an ominous source of bats and pigeon droppings, as it is in so many urban viaducts, the ceiling would be welcomed as the source of light for the whole area under the bridge.

The space under viaducts has often been considered “left-over” space. In recent years, with the growing public interest in urban living and making cities more livable, there has been new interest in taking advantage of the space under viaducts, and not just for organized parking. Parks and playgrounds and farmers’ markets are all uses that are now occurring under viaducts. It is time to consider what contributions the structure itself can make to the attractiveness of those spaces.



Photographs of concrete segmental bridges throughout the United States that represent solutions for sites with environmental sensitivity, tight urban right of way, long spans of water, crossing over active highways, and serving multi-modal transportation. Best value benefits have been recognized with over 350 awards for bridge owners.

Concrete Segmental Bridges

The Best Value Solution for Economy, Sustainability, and Beauty

by Linda Figg, FIGG

Bridge owners share common interests and responsibilities to achieve multi-modal transportation results that have the longest service life, lowest maintenance costs, are built quickly and efficiently, incorporate sustainable solutions, and are appreciated by the local and regional communities they serve. In creating sustainable solutions, the best value comes from a combination of economic efficiency, environmental sensitivity, and social involvement. When all of these factors come together, combining functionality, sculptural form, and a focus of over a 150-year service life, the bridge result is inspiring.

Economical Bridge Solutions

In the late 1970s and for a number of years beyond, alternate bridge design types were competitively bid against each other in construction whenever federal funds were over \$10 million dollars. Often, concrete segmental bridges were bid against other concrete and steel bridge types simply based on low cost as the selection factor. Concrete segmental bridges proved themselves in the marketplace with lower costs derived from repetition and speed of construction. Using local materials

and local labor, longer spans, fewer and more slender singular pier shapes, and construction methods that reduced activities in environmentally sensitive or traffic-packed sites made a difference to economical, efficient bridge solutions. These bridges were also recognized for pleasing aesthetics, which was simply a natural outcome of the overall design. The concrete segmental bridge industry grew throughout the United States building on the outstanding results in constructability and value. One example is given on the next page showing the photograph of the Interstate 93 (I-93) bridges in Boston and the description of cost savings.

Sustainable Success

One of the triple bottom line areas for sustainable success is economy. In addition to initial cost, reduced maintenance budgets for many owners mean best value solutions now take into account lower maintenance costs for saving money in the future. Also, environmental sensitivity and social involvement are other key areas evaluated in determining factors for resilience in our growing communities. Technology in concrete materials, equipment, and

cable-stay systems have aided in advancing concrete segmental bridges with new opportunities to reduce site footprints with longer spans. Examples include the new Harbor Bridge in Corpus Christi, Texas, with a 1655 ft concrete segmental cable-stay main span, and the new I-35W Bridge in Minnesota with a 504-ft concrete box girder main span.

Precast concrete segmental construction methods provide superstructure assembly from the deck level without using cranes on the ground. A good example is the Selmon Expressway in Florida shown on the next page. This allows traffic to remain in operation throughout construction while building in limited right of way. In Selmon's case, the bridge doubles vehicular capacity while only using a 6-ft-wide column in the medium of the existing 4-lane highway. The 9-mile AirTrain JFK in New York carries rail on a precast concrete segmental bridge down the middle of the busy Van Wyck Expressway. Over 160,000 vehicles a day were maintained during construction.

Social success means that the bridge respects the community it serves.



TEXAS

Rendering of the new Harbor Bridge in Corpus Christi, Tex., exemplifies benefits of concrete segmental bridges for long spans. The 1655-ft-long concrete segmental cable-stayed main span provides pier locations on land preserving the full channel for shipping needs with enhanced security and resilience, further preserving the natural and built environment.

It enhances the quality of life by preserving existing mobility during construction and creating the smallest footprint possible to keep adjacent lands for other growing community needs. Each bridge should honor the existing landscape and be in harmony with the surrounding environment while considering local plans that look to the future. Consciously integrating the bridge as a landmark with its function as a transportation asset provides the best value.

The Bridge's Beauty

The flexibility of concrete segmental construction to transform into many sculptural shapes and maintain efficiency in construction make it an ideal choice for aesthetically beautiful

bridges. The box-girder shape with long cantilever wings, a small bottom soffit, and smooth flat continuous shape with openness and light. Piers that transition with the box-girder bottom soffit are slender. Blending the superstructure and substructure shapes can appear as a holistic structure of one unified design. Each bridge is special with its own functional character for purpose and sense of style for beauty. Each bridge reveals a vision that the owner and community define as the best value solution to serve their goals. The FIGG Team is grateful for the opportunity to help many owners achieve their visions with sustainable, concrete segmental bridges for the future. 



MINNESOTA

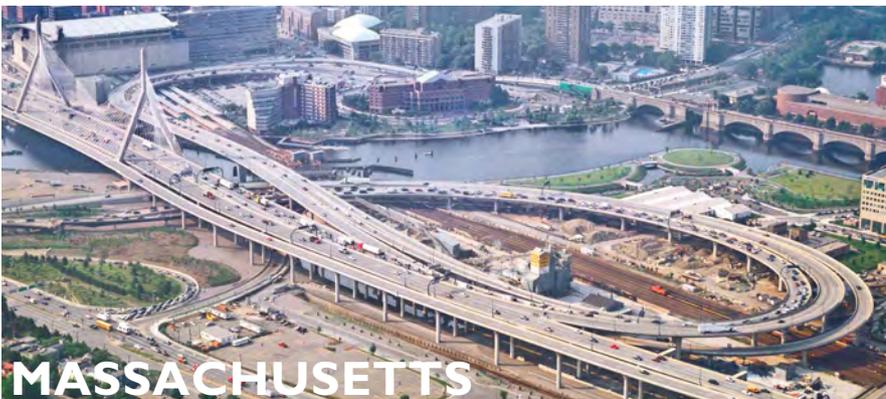
The new I-35W Bridge in Minnesota exemplifies the benefits of concrete segmental bridges for accelerated bridge construction (ABC) and long spans – the 10-lane, 504-ft main span was built with 120 precast segments in just 47 days; the entire bridge was designed and built in 11 months, 3 months ahead of schedule. Shown here is one of the 70-ft-tall curved concrete piers with sustainable LED lighting.



FLORIDA

The 5-mile, concrete segmental Selmon Expressway in Tampa, Fla, was bid for \$65/ft² and opened in July 2006. Shown here is one of the precast segments placed from the previously completed bridge with span-by-span construction of 142-ft spans. Traffic keeps moving below. 2400 ft of bridge superstructure was built in a month.

Concrete segmental bridges shown and discussed in this advertorial were all accomplished by FIGG for its customers. They include design, design/build, design/build/maintain, innovative financing, construction engineering inspection and related engineering services during construction to help get bridges built. FIGG is a family of companies exclusively specializing in bridges since 1978. For more information please visit figgbridge.com or call 800.358.3444.



MASSACHUSETTS

Aerial view of Interstate 93 concrete segmental bridges curving over 9 active railroad tracks twice in downtown Boston, Mass. The multi-level bridges had radii as tight as 212 ft. Segmental concrete boxes competed against steel boxes and provided a \$27 million savings on a \$79 million construction bid.

Pearl Harbor Memorial Bridge

by Dr. Steven L. Stroh, AECOM

Completed Pearl Harbor Memorial Bridge, New Haven, Conn. The first extradosed prestressed concrete bridge in the United States. Photo: Connecticut Department of Transportation.



On October 19, 2015, the Connecticut Department of Transportation (ConnDOT) held a bridge party and ribbon cutting for the southbound Pearl Harbor Memorial Bridge (PHMB), the second half of the new I-95 crossing of the Quinnipiac River in New Haven, Conn. The bridge was named by the Connecticut legislature as a memorial structure to honor the more than 2500 Americans, including 17 Connecticut residents, who died in the Japanese attack on Pearl Harbor on Dec. 7, 1941. The event was attended by more than 6000 people, including Connecticut Governor Dannel P. Malloy, U.S. Senator Richard Blumenthal, U.S. Representative Rosa DeLauro, Commissioner of Veteran Affairs Sean M. Connolly, and in the front row of the viewing area, two survivors of the attack on Pearl Harbor.

The choice of an extradosed prestressed bridge type for the PHMB was a creative concrete solution to challenging site conditions, and represented the first application of this new bridge type in the United States. The 515-ft-long main span was desirable for navigation clearance,

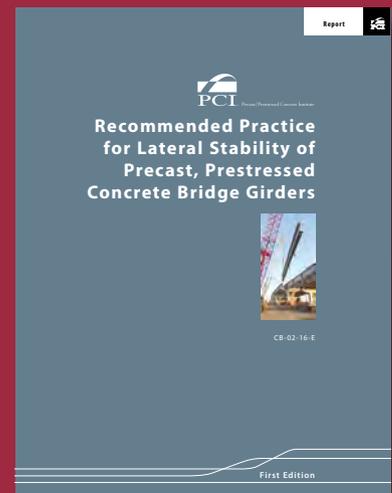


Bridge entry portal columns. Photos: Connecticut Department of Transportation.

but structural depth was limited by profile constraints required to meet the grades tying into the adjacent interchange, and precluded a conventional girder type bridge. A nearby airport constrained tower height that would have been necessary for a conventional cable-stayed bridge solution. The extradosed prestressed design allowed the desirable span, while staying within structural depth constraints and keeping the towers below the aviation clearance surface. The all-concrete design also provided a highly durable bridge solution to meet the 100-year service life design requirement.

The extradosed bridge type also met the fundamental project goal to provide a signature span worthy of the memorial character of the crossing. The towers are strong, simple, oval cylinder shapes, similar to what one might see on a ship. The outer webs of the girders are sloped to visually minimize the depth of the structure and provide a good balance between the visual mass of the girders and towers, and the superstructure is variable depth, which makes clear the girder's strong role in supporting the span. Representative DeLauro called the bridge "a work of art" and said she hoped all those who helped build

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This is a new comprehensive methodology to analyze the lateral stability of long slender bridge girders. Technology has enabled the manufacture of increasingly longer girders. Slender girders present a lateral stability concern. Each stage of a girder's transition from the casting bed to its final location in the bridge is considered. These conditions include when handling from the top with embedded or attached devices and supported from below during storage, transit, or in various conditions on the bridge during construction. These recommendations are the result of ground-breaking research conducted by Robert Mast in the 1990s. In 2007, the PCI Committee on Bridges clearly saw the need to address girder stability. They selected a specialized team to develop these recommendations. The producer members of the team have contributed substantial practical field experience. Together with a large number of designer practitioners, the team has developed an industry consensus recommended practice that provides methods to calculate the factors of safety during each of several stages of a girder's life. This is a must-have publication for all stakeholders in bridge design, fabrication, and construction.

This ePublication is available online at www.pci.org/epubs



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Cantilever construction on the northbound bridge. Photo: AECOM.



Grand opening party. Photo: AECOM.

it had carved their names in the concrete somewhere to be remembered.

An interesting design consequence of the phased construction of the twin structures and the stiff extradosed superstructure was the design of the connection between the superstructure and the towers. Initially, an integral connection was investigated. But considering the combined effects of creep and shrinkage, foundation stiffness (including a bracketing of stiffness), and the “leaking” of secondary post-tensioning effects between the second superstructure and the first superstructure, an efficient design could not be found. When the effect of the range of design values was evaluated, there were instances for which tension limits were exceeded on one side of the member with the low end of bracketed parameters, and then, assuming the high side of the bracketed values, tensile limits were exceeded on the other side of the member. Compression was also at the limits. Increasing member size made restraint forces worse. The solution was to build more flexibility into the system by adding bearings. For a single bridge, a solution would have been possible with an

integral connection, but with the twin decks sharing a central tower, this design issue was critical and forced a solution using bearings.

The bridge was completed 8 months ahead of schedule and on budget, providing a practical solution to a real-world transportation need. The project also highlights concrete as a creative solution in providing a landmark bridge to be enjoyed by the public. **A**

Dr. Steven L. Stroh is a vice president and complex bridges practice leader for AECOM in Tampa, Fla.

EDITOR'S NOTE

For more information on this bridge see the Fall 2012 issue of ASPIRE.™ For more information on extradosed prestressed bridges see Summer 2015 issue of ASPIRE. For a discussion of the installation of the cable stays for this bridge, see the Winter 2016 issue of ASPIRE.



SIMPLICITY AND TRANSPARENCY IN STRUCTURAL DESIGN

Strut-and-tie method

by Dr. Oguzhan Bayrak, University of Texas at Austin

The 2016 Interim Revisions to the 7th edition of American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* place a greater emphasis on delineating disturbed regions (D-regions) of reinforced concrete members from the beam regions (B-regions). Whereas the use of legacy design methods is appropriate in B-regions, the AASHTO LRFD specifications recommend the use of the strut-and-tie method (STM) in D-regions as an alternative with a strong physical basis to the more prescriptive or empirical legacy methods.

To the extent it relates to STM, and in an effort to emphasize the importance of simplicity and transparency in structural design, in this article I will focus on the structural design of reinforced concrete beams. In broad terms, the design of reinforced concrete beams can be accomplished either by following the rules of legacy design methods or by using STM. Legacy design methods, such as sectional design methods, have long been used in designing reinforced concrete beams.

In such designs, axial load, shear force and bending moment diagrams are drawn first. Following the development of these diagrams, critical sections along the length of a beam are identified. By using the forces present at critical sections, those sections are designed to have sufficient axial, flexural and shear strength to meet the appropriate code requirements. In addition, all postulated failure modes have to be considered and the member has to be detailed so as to preclude all failure modes such as reinforcing bar anchorage failure and bearing failure.

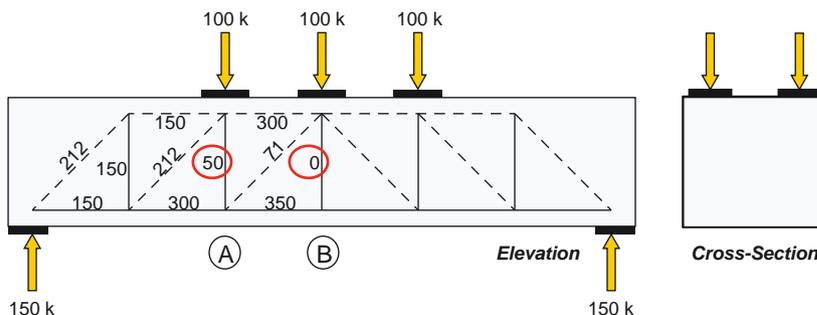


Figure 1. Longitudinal strut-and-tie model of a rectangular beam with compression chord loading. All Figures: Oguzhan Bayrak.

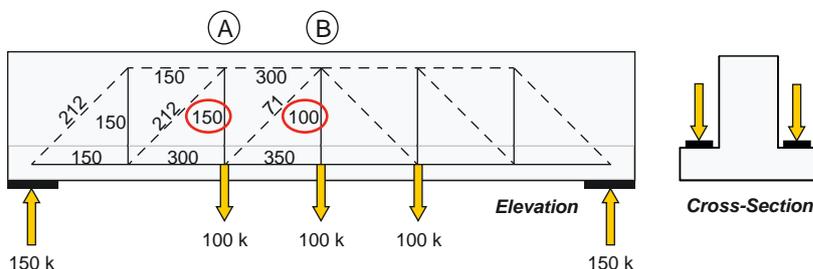


Figure 2. Longitudinal strut-and-tie model of an inverted-tee beam with tension chord loading.

Alternatively, and especially in D-regions, a designer may use STM in designing and detailing a reinforced concrete member. The use of STM allows a designer to simplify internal stress paths by using a simple truss model. In this way, a designer can proportion the longitudinal and transverse reinforcement and ensure that the specified compressive strength of concrete is sufficient and that reinforcing bar anchorage requirements are met.

To illustrate the simplicity and transparency of STM, let us use the design of an inverted-tee beam as an example. For brevity, I will focus on hanger reinforcement design rather than all aspects of the structural design of an inverted tee. Figure 1 includes an STM model for a rectangular beam that is loaded on its compression chord, and Figure 2 is an STM model for a ledge-loaded inverted-tee beam.

Since both beams are of equal length and the design loads act at the same locations along the beam length, both beams have identical bending moment and shear force diagrams. The flexural and shear designs resulting from these diagrams would be identical, except for the fact that if legacy design methods

are used in design, a separate check for the hanger reinforcement becomes necessary and additional web reinforcement must be provided in the vicinity of loads applied at the beam ledges.

The use of STM makes this process much more transparent. The vertical tie forces at sections A and B are significantly higher in a truss loaded at its tension chord (Fig. 1 and 2). The 100-kip additional vertical tie forces at sections A and B clearly show that the loads applied at the tension chord have to be transferred up to the compression chord of the beam before they are transferred into the supports. Therefore, using STM, an additional step for the design of hanger reinforcement is not necessary.

Perhaps more importantly, the truss models shown in both figures clearly demonstrate the identical nature of the demand on flexural tension reinforcement and diagonal struts, for both loading scenarios. The transparency of the load-transfer mechanism evident in the truss models render STM to be a powerful design technique.

Historically, D-regions have been designed with empirical methods that require the use of a long list of design checks. The hanger reinforcement design in an inverted-tee beam, as discussed previously, is one such example. Additional checks to complete an inverted-tee design, by using legacy design methods, include ledge punching check, shear-friction check, and bearing stress check, and others as articulated in the beam ledge design provisions of the AASHTO LRFD specifications. As recognized by the specifications, if an inverted-tee beam is designed by using STM, additional checks are not necessary. The use of a cross-sectional truss model, as shown in Fig. 3, in addition to the longitudinal truss model shown in Fig. 2, is sufficient.

In conclusion, the greater level of transparency and the reduced level of empiricism offered by STM render this technique an excellent alternative in structural design. A designer who can visualize the load paths between the loads and the supports is

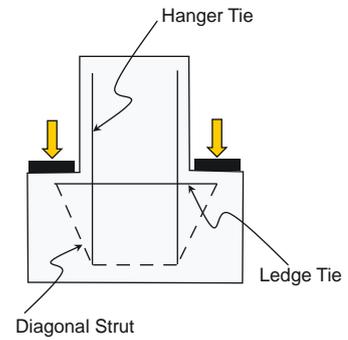


Figure 3. Cross-sectional strut-and-tie model for inverted-tee beam.

less likely to skip a design step and more likely to develop a greater level of confidence in his/her design. In my view, as we move towards further improving our design codes, reducing empiricism and increasing transparency should be taken as important objectives. The recent improvements made to the STM provisions of AASHTO LRFD specifications are aimed at accomplishing these goals. In my upcoming articles, I will explain how these important goals are accomplished in the improved STM provisions of our bridge design specifications. 

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Designing Post-Tensioned Bridges to Accommodate Nondestructive Evaluation



by Reggie Holt, Federal Highway Administration

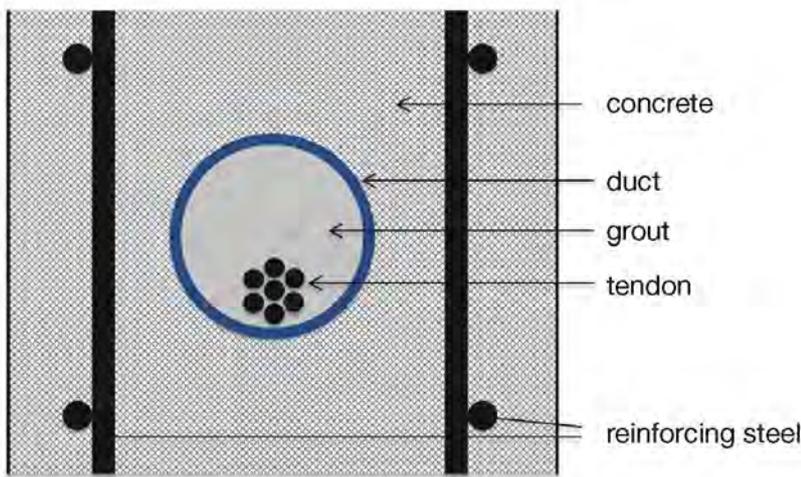


Figure 1. Typical post-tensioning strand encasement. All Figures and Photos: WSP/Parsons Brinckerhoff.

Post-tensioning (PT) has increased the strength and serviceability for many of our nation’s bridges and will continue to play an important role in the design of future bridges. In-service post-tensioned bridges have proven to be very durable, however given the significant contribution that PT tendons provide to the bridge’s load-carry capacity, there is great interest in assessing their in-service condition. Inspection of PT strands can be difficult due to their multiple layers of encasement, which typically include grout, ducts, reinforcing steel, and structural concrete (Fig. 1).

Nondestructive evaluation (NDE) technologies provide the best tools and techniques to assess the condition of PT tendons. NDE technologies are advancing rapidly and are offering increased assessment capability and portability. Past PT NDE research has focused primarily on choosing the appropriate NDE technology for the application, which many times has reduced the effectiveness of the

NDE technology. The Federal Highway Administration (FHWA) has initiated research tasked to do the reverse, which is to design and detail the bridge to accommodate the NDE technology in order to maximize the effectiveness of the most promising tools.

Research Goals

The primary goal of this research is to reduce the likelihood of premature deterioration of post-tensioned bridge components and systems by identifying issues early through the use of NDE and provide better information about load-carrying capacity. This research will develop guidance for the design and detailing of post-tensioned bridges and tendon components to facilitate application of promising NDE methods. The effort is focused on evaluation of grouted internal and external PT systems. The ultimate goal is to find combinations of NDE, PT system details, and bridge superstructure details, that can be implemented into future

structures to increase the reliability and ease of inspection for post-tensioned systems.

Research Approach

The first task for this research was to identify promising and readily available NDE technologies with the ability to detect strand corrosion, grout voids/condition, and remaining prestress. No one NDE technology can detect all the possible issues, however many can accurately detect one or more. Each of these NDE technologies was assessed on its ability to be applied to a PT bridge structure and provide accurate assessment data. Both strengths and limitations for each NDE technology were documented along with any current use in assessing and inspecting PT bridges. The numerous promising NDE technologies investigated are listed below.

- Acoustic emission
- Electrically isolated tendons
- Ground-penetrating radar
- Half-cell potential
- Impact echo
- Infrared thermography
- Radiography
- Time domain reflectometry
- Ultrasonic testing
- Visual inspection

In addition, this research identified PT system components and bridge superstructure details that hinder the NDE method’s ability to effectively evaluate the PT tendon. Using this information, practical details for new design and recommendations on how to alter PT system components and bridge superstructure elements will be developed. As one might expect, the applicability and accuracy of many NDE technologies are affected by the type of



Figure 2. Monitoring at post-tensioning anchorage.

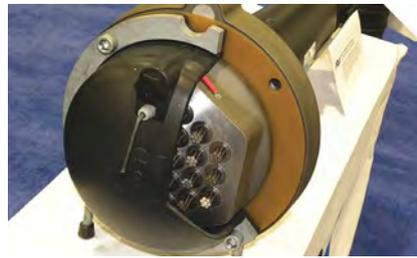


Figure 3. Electrically isolated tendon anchorage.

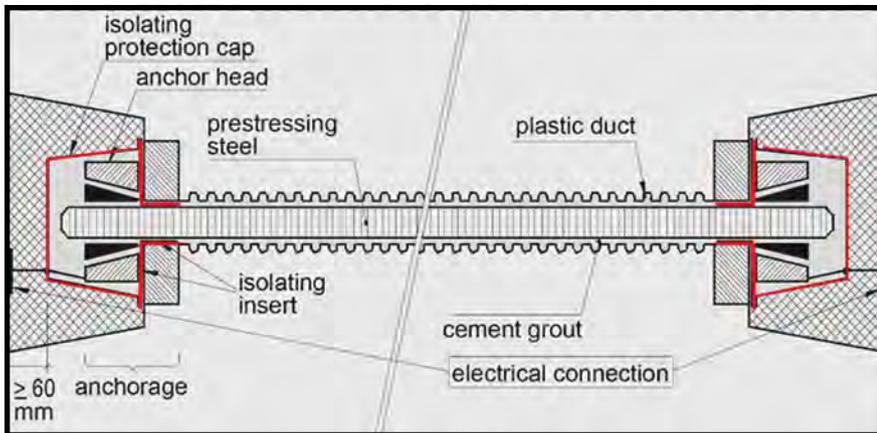


Figure 4. Electrically isolated tendon schematic.

encasement around the PT strand with the typical encasement variables being metal versus plastic PT duct, internal versus external PT tendon, and amount of reinforcing steel.

Research Findings

The research identified four promising NDE technologies that could be integrated into new construction and be used for routine inspection of the PT tendon throughout the lifespan of the structure. These promising technologies included electrically isolated tendons (EIT), time domain reflectometry, half-cell potential, and ultrasonic testing methods. The literature review and findings from this research are available electronically at www.atlss.lehigh.edu/documents/Reports/ATLSS_Report_14_01.pdf.

Three of the four identified promising NDE technologies will require additional research in order to thoroughly demonstrate their applicability and effectiveness in PT bridges. However, the EIT technology is very mature and routinely used in Europe and could easily be deployed in the United States. In fact, EIT is already recognized in the PTI/ASBI *Guide Specification for Grouted Post-Tensioning* as a viable PT

system. The specification identifies an EIT post-tensioning system as protection level three (PL-3), which represents the highest level of PT tendon protection possible. Another major benefit identified in the research is EIT's ability to provide a very rigorous QC check during construction. EIT readings during construction can accurately detect breaches in the PT tendons protection system.

Future Opportunities

FHWA has started additional research to advance the electrically isolated tendon (EIT) technology (Fig. 2-4). The greatest needs to make this technology fully implementable are system qualification specifications and testing along with system detailing guidance. The recently started FHWA research will address these needs by developing system specifications and qualification testing along with guidance on EIT system detailing, installation, and monitoring. The research team will deliver the draft specification to the PTI/ASBI M50 Committee in the spring of 2016 and we look forward to implementing this promising technology in our nation's bridges in the near future. 



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NORTH CAROLINA

The state's department of transportation uses weighting factors, bundling to gain most bang from legislature's extra funding in next 2 years

by Tom Koch and Todd Garrison, North Carolina Department of Transportation

The new Herbert C. Bonner Bridge in Dare County, N.C., which begins construction this spring, features a 2.8-mile-long structure composed of precast concrete segmental box girders and prestressed girder spans. The new bridge will parallel the existing one, the only access to Hatteras Island. Photo: HDR Inc.

North Carolina's backlog of structurally deficient bridges has been targeted by the state's legislature for both fiscal years 2016 and 2017. With \$150 million added to the budget over the two-year period, the North Carolina Department of Transportation (NCDOT) is using a variety of techniques, including bridge prioritization, design-build delivery methods, and bundling of projects to maximize the effectiveness of this mandate.

The addition of an extra \$50 million in 2016 and \$100 million in 2017 to address deficient bridges was provided with the directive to address the state's core needs by using objective criteria rather than reacting to political pressures. This funding will significantly reduce the 2167 structurally deficient bridges (out of 13,400) in the state. NCDOT is fortunate to have legislators in North Carolina who see the growing problem and understand the need to act now.

As with many states, North Carolina saw a boom in post-war highway construction, and many of those bridges have reached the end of their useful lives. Over the years, that total continues to grow and requires replacements that provide few disruptions to the traveling public.

To determine how best to optimize the funding, NCDOT has ranked the bridges using its Priority Replacement Index

(PRI). This index assigns values to a number of bridge measures (for example, average daily traffic, load rating, structure condition rating, and detour length) and determines replacement priorities. In addition to that approach, NCDOT initiated a low-impact bridge replacement program, which focuses on replacing rural, low-volume bridges in kind rather than providing substantial upgrades. This ensures projects can be completed as quickly as possible and spreads the money to more bridges needing replacement.

Design-Build Method Growing

NCDOT also makes use of the design-build delivery method to encourage innovation and custom efficiencies by each bidder. Design-build has become an important tool as it speeds up the construction process by allowing site work to begin as designs are completed.

One of the state's first successes with design-build projects was the US Route 17 Washington Bypass project in Beaufort County. The precast concrete bridge consists of 140 spans (116 spans plus two parallel structures of 12 spans) that are each about 121 ft long. Bidders were scored on their creativity and estimated cost. Adjustments were made to the proposal to lower costs based on feedback.

Larger projects often use the design-build process.

Larger projects often use the design-build process, such as the ongoing replacement of the Herbert C. Bonner Bridge, an existing 2.5-mile-long structure in Dare County on the Outer Banks that serves as the only road access from the mainland to Hatteras Island. The 2.8-mile-long replacement structure, which will parallel the existing bridge, will use a segmental box-girder design for the major spans and precast concrete girders for the approach structures. Construction will begin this spring. This represents a major milestone, as the bridge has needed replacement for years but was held up due to legal actions.

The work also includes an interim bridge on NC 12 near Pea Island that replaces the existing temporary bridge that was constructed over an inlet created during Hurricane Irene in 2011. The interim bridge will be constructed with enough durability to last until a permanent solution is determined that is compatible with stakeholder interests. It will feature 47 spans of 50-ft-long cored-slab units, with virtually the entire bridge composed of precast concrete elements. This construction, let under a separate design-build project, has begun.



One of the first projects completed using the design-build delivery method in the state was the US Route 17 Washington Bypass bridge in Beaufort County, N.C. It was completed using a gantry system that drove piles, set precast concrete bents, and erected beams from above to minimize impact to the wetlands below. Photo: Flatiron.

The use of design-build techniques also has led to the bundling of several bridge projects.

The use of design-build techniques also has led to the bundling of several bridge projects through NCDOT's design-build delivery method. Initially, NCDOT bundled seven to twelve bridge replacements in a division into a bid. Recent feedback from contracting partners showed that bidders preferred bundles of five to seven projects of a similar bridge type in a smaller area. That approach reduces risk and optimizes use of cranes and crews.

Three Types of Concrete Bridges

In general, NCDOT designs three types of concrete bridges.

1. Approximately 50% of the bridges built each year are cored-slabs: precast, prestressed, and post-tensioned concrete voided slabs with an asphalt or concrete overlay. This bridge type is cost-effective and long lasting, and contractors are familiar with it. It is the workhorse design for our shorter-span bridges.
2. Longer bridges with low truck traffic are typically designed with precast, prestressed

concrete box beams.

3. Longer bridges and those with more truck traffic are designed with prestressed girders. Unique designs are used for projects with unusual or challenging constraints.

One such project is the Yadkin River Veterans Memorial Bridges, a dual-highway bridge that improved safety and accessibility on Interstate 85 (I-85) between Charlotte and Greensboro. The 2900-ft-long, 21-span structures used 77-in.-deep precast concrete for economical fabrication (PCEF) bulb-tee prestressed concrete girders up to 140 ft long made continuous for live load. The design features a single, super-elevated horizontal curve with a 17,000-ft radius that eliminated the series of tangents and curves in the previous structure.

More Stakeholder Input

The Yadkin River project, as well as the new Bonner Bridge, point to the trend toward negotiating with more stakeholders on projects. Large projects receive a great deal of feedback, with more organizations interested in every aspect as they realize how significant the bridges' impact can be on its community. The goal is to find the best balance of all factors, as in ranking the projects, to maximize the benefits to all interests.

Certainly, environmental concerns have grown in importance as more is understood about the environment's impact on the bridge and vice versa. NCDOT has worked hard to streamline the environmental-permitting process to ensure timely

construction schedules while addressing issues that partners and environmental agencies raise. The process is smoother today than it has in the past despite becoming more stringent.

NCDOT remains optimistic that its inventory of deficient bridges will be reduced even as work on more ambitious projects continues. Currently, NCDOT is beginning environmental studies on the \$440-million Mid-Currituck Bridge, a two-lane, 7-mile-long toll-road bridge that will alleviate congestion on the only crossing of the Currituck Sound along the coast.

With such projects as the Bonner, Pea Island, and Mid-Currituck projects moving forward, along with an expanded program to eliminate structurally deficient bridges, NCDOT expects a busy and productive year. The department is extremely fortunate that the state's legislative leaders have taken a great interest in replacing deficient bridges and expanding access to isolated areas. **A**

Tom Koch is the state bridge engineer and Todd Garrison is an engineering supervisor in the Structures Management unit of the North Carolina Department of Transportation in Raleigh.

EDITOR'S NOTE

Project articles on the Washington Bypass and the Yadkin River Bridge appeared in the Fall 2008 and Winter 2014 issues of ASPIRE,™ respectively.

TDOT Fast Fix 8 Project

by Lia Obaid, Tennessee Department of Transportation, and Ted Kniazewycz, Gresham, Smith & Partners



Placing precast concrete end wall on existing pier to make the new abutment. All Photos: Gresham, Smith & Partners.



Precast concrete deck panels with longitudinal joints over box beams and splice bar connections between panels.

The construction manager/general contractor (CM/GC) project delivery method is being piloted in three projects in Tennessee with a total aggregate of \$200 million in construction costs. The pilot program sunsets after 5 years and is effective July 1, 2014 to July 1, 2019. CM/GC is a project delivery method that allows the Tennessee Department of Transportation (TDOT) to engage a construction manager during the design process of a project to provide constructability input through a competitive qualification-based selection process. Following the design process, TDOT and the construction manager negotiate a guaranteed maximum price for the construction of the project based on the defined scope and schedule.

The I-40 project, also called the Fast Fix 8 project, had an average daily traffic of 130,000, and the project site limits were in downtown Nashville. Therefore, time was very valuable for the roadway users and stakeholders. Per the innovative CM/GC process, which shortens delivery time and reduces design errors, TDOT decided to close I-40 for 10 weekends for safety and efficiency, and kept all lanes operational during the work week.

The Fast Fix 8 project was the first CM/GC project by TDOT. It was a good fit for this method due to the opportunity to explore innovation and technology, and because it could deviate from standard materials and design features with value engineering and constructability reviews throughout the preconstruction and construction phase.

Concrete Solutions

In order to complete the project on the tight timeline established by TDOT, precast

concrete bridge elements were used on many of the bridges. Those elements include precast, prestressed concrete box beams; full-depth prestressed concrete deck panels; precast concrete end walls; and precast concrete approach slabs. All of these concrete elements were fabricated off site at a precasting facility in Lexington, Ky.

The most complex elements to fabricate were the precast concrete end walls. The design of the project eliminated the end spans on the existing bridges and modifications to the existing bents allowed them to function as abutments. The individual pieces were custom fabricated to fit around the existing riser blocks on the bent cap and to wrap around the new box beams. These elements were pinned to the caps and were joined by a shear key filled with a specialty concrete mix.

The full-depth precast concrete deck panels were prestressed transversely for the bottom mat of reinforcement and used nonprestressed reinforcing steel for the top-mat reinforcement. Each panel spanned over three or four bays of beams. The panels had open joints over the box beam to provide a positive connection for composite action. The connection between panels used a contact lap-splice bar in a socket.

The joints and sockets were filled with high-strength concrete. The special mixture (designated as TDOT Class X) was capable of reaching 4 ksi in 4 hours and could be batched and delivered in a ready-mixed concrete truck. The pot life for the concrete was 1 hour, which allowed enough time for a truck to unload up to 4 yd³ before the material began to lose its workability.

The mixture was developed by the contractor, the ready-mix supplier, the admixture supplier,

and the Concrete Institute at Middle Tennessee State University. It had exceptional resistance to chloride penetration, bond strength, and shrinkage. In contrast, if the high-strength material had been small-batch mixed with a bagged material, it would have taken over 36,000 bags for this project. This class “X” material was instrumental in the success of this project.

Conclusion

CM/GC with accelerated bridge construction was the best approach because it provided TDOT the flexibility to respond to uncertainty with the Fast Fix 8 project in real time. Also, it shortened the delivery time by more than 2 years and created a strong team work environment. In addition, the contractor was able to meet with the public early and become committed to the public's needs, the project goals, and the design. The contractor was able to adjust the construction approach because it was not restricted to a hard bid price.

The use of precast concrete bridge elements was key in achieving an early project completion date. The ability to quickly fabricate the various elements from readily available materials meant that the bridge components could be delivered on an accelerated schedule. Also, because components were manufactured in a precasting facility, the project team knew that a superior-quality product with excellent performance would be provided. ▲

Lia Obaid is the assistant director of construction of the Tennessee Department of Transportation in Nashville. Ted Kniazewycz is a senior bridge engineer with Gresham, Smith & Partners in Nashville.

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Unique Approaches to Erecting Long-Span Girders

by Dr. Keith Kaufman, Knife River Corporation

Improved materials, handling equipment, and shipping equipment continue to push the fabrication limits of precast, prestressed concrete girders. Concrete compressive strengths at transfer of prestress and at 28 days may exceed 7 and 10 ksi, respectively. Precast, prestressed concrete fabricators have constructed stressing beds capable of jacking over 3 million pounds. Many states or regions have adopted bulb-tee cross sections to receive the high prestressing loads and improve the response to handling, shipping, and erection stability.

Design engineers take advantage of these improvements to increase span lengths. The project environmentalist, biologist, and hydrologist restrict waterway construction and limit in-water activities such as work bridges and foundation construction. With these time and geometry restrictions, contractors find unique ways to erect these long spans.

Single Pick

One approach to erect a long, heavy girder is to mobilize a large crane and utilize a single pick. Sling orientation



Passing a girder between two cranes using a load triangle (inset). Photos: Knife River Corporation.

limits, such as 60 degrees, and modifications to the lifting system are often required. The girder stability must also be evaluated for the additional horizontal compressive forces. Horizontal spreader beams can be used to eliminate the horizontal forces delivered to the girder. Bearing elevations that are different at each end of the girder can lead to challenges as the statics of the system change when one end of the girder rests on the support bearing before the other end does.

Passing Girders between Two Cranes

Another technique is to pass the girder from one crane to another crane located on the opposite bank of the crossing. The long girder is shipped using a rear steering unit and the front jeep or tractor. The steering unit is backed into the site and one crane lifts one end of the girder off the rear steering unit. The rear steering unit is then disconnected and moved out of the way. The other end of the girder remains securely attached to the front jeep or tractor. The crane rotates as the girder/truck assembly backs up, moving the girder toward the other bank.

As the first crane reaches its radius capacity, the load is transferred to a second crane located on the opposite bank. The first crane then swings into position to pick the other end of the beam off the truck. The two-crane pick completes the erection.

Load transfer between cranes may involve a load triangle with the two cranes attached to the top two corners of the triangle. The triangle rotates as the load is transferred to the second crane. It is important to not attempt to change the position

Decked bulb-tee being erected by a single pick. Photo: Morrison Structures Inc.



Single-span girder launching system where truck pushes girder across the launching girder. Photo: Knife River Corporation.

of the beam while both cranes share the load, that is, the position of the beam must be stationary as the load is transferred between cranes. This will minimize exceeding crane capacities if the load is accidentally shifted between cranes.

Girder Launchers

Many bridge contractors own or have access to girder launchers. A launcher typically consists of a single-span structure with a mobile support system (cart) that can travel across the launcher. It is important that the girder restraint system be maintained

to the truck and the trolley during this operation. Once the girder reaches the desired location, cranes are connected to the lifting points to complete the erection.

A unique launching system may include a multi-span launcher that includes a pair of mobilized beam launcher carts. This system allows all girders for the bridge to be delivered to one abutment and moved to the desired span. The shipping equipment is backed up to the abutment. A crane lifts the girder and places it on the cart located on the launcher. The truck continues to back into the site until the crane can lift the other end of the girder and place it on the second cart. At all times, the restraint of the girder is maintained at a minimum of one end of the girder. The girder is then moved along the launching girders until it reaches the appropriate span. The girder is then erected into its final position or into a temporary position until the launcher can be removed. Launchers are often supported on the new structure or on temporary bents that may be supported on the foundations from an existing structure that is being replaced.

Stability is Key

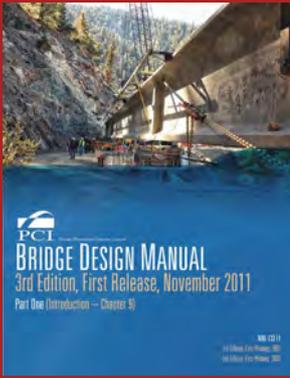
Erection of the girders is often the most exciting part of a project. This phase of the project presents the transition milestone between the substructure and superstructure. Several techniques have been discussed that can be used to erect large girders. In all situations, the girder stability must be evaluated and maintained. Costly equipment and teamwork are both required to complete this phase of the project.

A fully braced superstructure ready to receive the deck and rails is the goal before the end of the day. The creativity of a good bridge contractor often allows the bridge engineer to *aspire* to design these challenging structures. 

Dr. Keith Kaufman is the chief engineer with Knife River Corporation—Northwest in Harrisburg, Ore.

EDITOR'S NOTE

For more information, please consult the Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders published by PCI.



PCI BRIDGE DESIGN MANUAL

3rd Edition, Second Release,
August 2014

This up-to-date reference complies with the fifth edition of the *AASHTO LRFD Bridge Design Specifications* through the 2011 interim revisions and is a must-have for everyone who contributes to the transportation industry.



The PCI State-of-the-Art Report on THE CURVED PRECAST CONCRETE BRIDGES

This report details the application of curved precast concrete bridge design, fabrication, construction techniques, and considerations through the study of twelve related projects and constitutes a state-of-the-art report on this topic.



The PCI State-of-the-Art Report on SEISMIC DESIGN OF PRECAST CONCRETE BRIDGES

Because modeling techniques have not yet been implemented for jointed details, the focus of this report is on procedures for the evaluation of system response and the detailing of connections for emulative behavior.



The PCI State-of-the-Art Report on PRECAST CONCRETE PAVEMENTS

This report is the combination of four documents on the use of precast concrete pavement systems (PCPS). The documents were developed through a cooperative agreement between PCI and the Federal Highway Administration.

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FR 2142 over Interstate 25 Airport Interchange. Photo by Fernando Quiroga.



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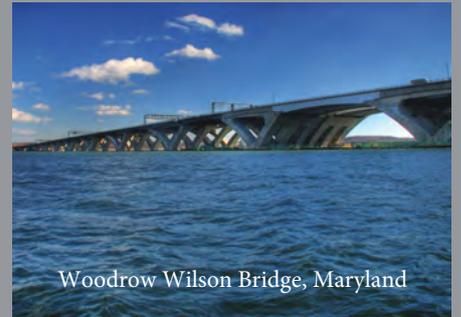
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CONCRETE CONNECTIONS

Concrete Connections is an annotated list of websites where information is available about concrete bridges. Links and other information are provided at www.aspirebridge.org.

IN THIS ISSUE

<http://acceleratedbridge.vermont.gov/>

This is a link to the Vermont Agency of Transportation's Accelerated Bridge Program website that is mentioned in the Project Profile article on page 14. It has links to all of the completed projects, including documents related to each project. Two projects are highlighted; a video of the installation and the results of a survey after completion are provided for one project.

<http://www.trb.org/Main/Blurbs/168046.aspx>

This is a link to the SHRP 2 Report S2-R04-RR-2: *Innovative Bridge Designs for Rapid Renewal: ABC Toolkit*. The document describes standardized approaches to designing and constructing complete bridge systems for rapid renewals. This resource was used to identify strategies employed in the Caltrans replacement of the Fort Goff Creek Bridge described in the Project Profile article on page 18.

<http://www.fhwa.dot.gov/bridge/abc/index.cfm>

This is a link to FHWA's Accelerated Bridge Construction (ABC) website, which provides a variety of resources for projects such as those in the Vermont Agency of Transportation's Accelerated Bridge Program and Caltrans' Fort Goff Creek Bridge replacement project.

<http://www.wsdot.wa.gov/Projects/SR520Bridge/BridgeAndLandings/>

This is a link to the WSDOT project website for the SR 520 Floating Bridge and Landings Project that is described in the Project Profile article on page 26. Project photos, renderings, and some videos are available on the website.

www.atlss.lehigh.edu/documents/Reports/ATLSS_Report_14_01.pdf

This is a link to the initial report from the FHWA research project "Designing and Detailing Post Tensioned Bridges to Accommodate Non-Destructive Evaluation." The report provides a literature review and initial findings on promising NDE technologies for post-tensioned bridges as discussed in the FHWA article on page 36.

http://abc-utc.fiu.edu/index.php/technology/monthly_webinar_archive/

This is a link to the webpage for archived monthly webinars sponsored by the ABC-UTC at Florida International University (FIU) where a recent webinar on the TDOT Fast Fix 8 project that was discussed in the Creative Concrete Construction article on page 40 can be accessed.

Bridge Technology

NEW <http://www.fhwa.dot.gov/construction/sibc/>

This is a link to a website with a range of resources on slide-in bridge construction (SIBC) including six short courses just developed by Institute for Transportation at Iowa State University for FHWA. These user-friendly training materials can be downloaded from the FHWA website for individual use or for instructor-led events.

NEW <http://www.nzta.govt.nz/assets/resources/research/reports/577/577-criteria-and-guidance-for-the-design-of-integral-bridge.pdf>

This is a link to a report released by the New Zealand Transportation Agency that provides a summary of current practices relating to the design and construction of integral and semi-integral bridges.

NEW <http://www.gao.gov/assets/680/673436.pdf>

This is a link to a report released by the U.S. Government Accountability Office that examines the current conditions of the nation's bridges, as well as changes in bridge conditions that have occurred over the last 10 years.

<http://www.fhwa.dot.gov/research/resources/uhpc/publications.cfm>

This is a link to a webpage that has links to publications produced by FHWA's research and development program on the performance and use of ultra-high performance concrete (UHPC).

www.concretebridgeviews.com

This is a link to access the 79 issues of *Concrete Bridge Views* (formerly *HPC Bridge Views*), an electronic newsletter published jointly by the FHWA and the National Concrete Bridge Council (NCBC) to provide relevant, reliable information on all aspects of concrete in bridges. The recently released issue focusses on durability of bridge decks and joints.

www.aspirebridge.org

Previous issues of *ASPIRE*TM are available to search and as pdf files, which may be downloaded as a full issue or individual articles. Information is available about free subscriptions, advertising, and sponsoring organizations.

www.nationalconcretebridge.org

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

Bridge Research

NEW <http://www.fhwa.dot.gov/advancedresearch/pubs/16017/16017.pdf>

This is a link to an FHWA report that investigates alternative cementitious materials for applications in sustainable transportation infrastructure.

<http://www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/14090/14090.pdf>

This is a link to the FHWA Report FHWA-HRT-14-090 which is titled "Bond Behavior of Reinforcing Steel in Ultra-High Performance Concrete" which is available for download as a PDF on this website. It will eventually be reformatted and posted in HTML as a webpage.



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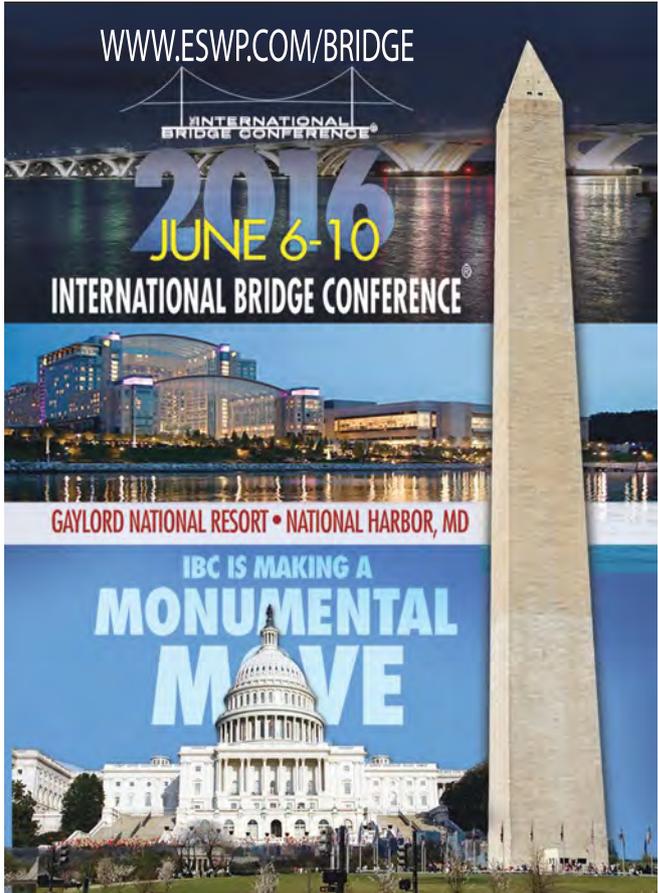
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2016 Interim Changes Related to Concrete Structures, Part 2



by Dr. Dennis R. Mertz

The discussion of the agenda items that the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS) adopted at their 2015 annual meeting begun in the last issue continues in this column. The agenda items represent revisions and additions to the 7th edition of the *AASHTO LRFD Bridge Design Specifications*. This column reviews the 2015 concrete-structures agenda items, which became the 2016 Interim Revisions, that have been published and are now available from AASHTO. The remaining agenda items related to concrete structures, agenda items 6 through 9, follow.

Agenda Item 6

The 2013 interim revisions extended the minimum yield strength of reinforcement for use in selected design articles to 100 ksi. This included its use in reinforced-concrete bridge decks. However, the use of a yield strength of 100 ksi in connection with Equation 5.7.3.4-1, the crack-control equation that limits bar spacing, results in unrealistically close bar spacing in bridge decks. Agenda item 6 adds that bar spacing need not be less than 5 in. for control of flexural cracking where higher strength reinforcement is used. In addition, it restores commentary removed with the 2005 Interim Revisions that suggests, for calculation purposes, a value of d_c not greater than 2.0 in. plus the bar radius may be used.

Agenda Item 7

Agenda item 7 increases the compressive stress limit at transfer in Article 5.9.4.1.1 to $0.65 \bar{f}_c$ for pretensioned and post-tensioned concrete components, including segmentally constructed bridges. While previous research¹ suggests that the concrete compressive stress limit at transfer for prestressed concrete components can safely exceed $0.65 \bar{f}_c$, concrete in the precompressed tensile zone subjected to compressive stresses at transfer greater than $0.65 \bar{f}_c$ can experience microcracking, leading to unconservative predictions of the external load required to cause cracking.²⁻⁵

Agenda Item 8

Agenda item 8 represents a complete rewrite of the strut-and-tie method (STM) of

Article 5.6.3. In addition, concrete members are delineated as being composed of beam regions (B-Regions) and disturbed regions (D-Regions) with specifications for the design of each. The proposed provisions take advantage of an extensive research effort sponsored by the Texas Department of Transportation at the University of Texas-Austin,^{6,7} which involved a thorough examination of previous tests, primarily of deep beams; additional large-scale, deep-beam tests at University of Texas-Austin; and a comparison of current AASHTO provisions and those which have been used in Europe for many years. The most significant changes in the proposed provisions are

- elimination of distributed reinforcement if an associated efficiency factor is used,
- use of simple concrete efficiency factors similar to those in the *fib* (International Federation for Structural Concrete) *Model Code for Concrete Structures*,
- use of the existing AASHTO confinement factor to increase the usable concrete strength where there is clear distance on all sides of a bearing plate or load plate,
- provision of expanded design rules to size the nodes in the STM,
- use of a single panel truss model for shear span-to-depth ratios less than 2.0,
- elimination of principal tensile strain as a criterion for nodal capacity, and
- elimination of a separate strut capacity check away from the nodes.

Agenda Item 9

The revisions to Chapter 5 of the *AASHTO LRFD Bridge Design Specifications* in Agenda item 5, discussed in the last issue, include the term “equilibrium density” as determined by ASTM C567 in the definition of lightweight concrete. Agenda item 9 adds the term “equilibrium density” to Article 8.2.3 of the *AASHTO LRFD Bridge Construction Specifications* for consistency.

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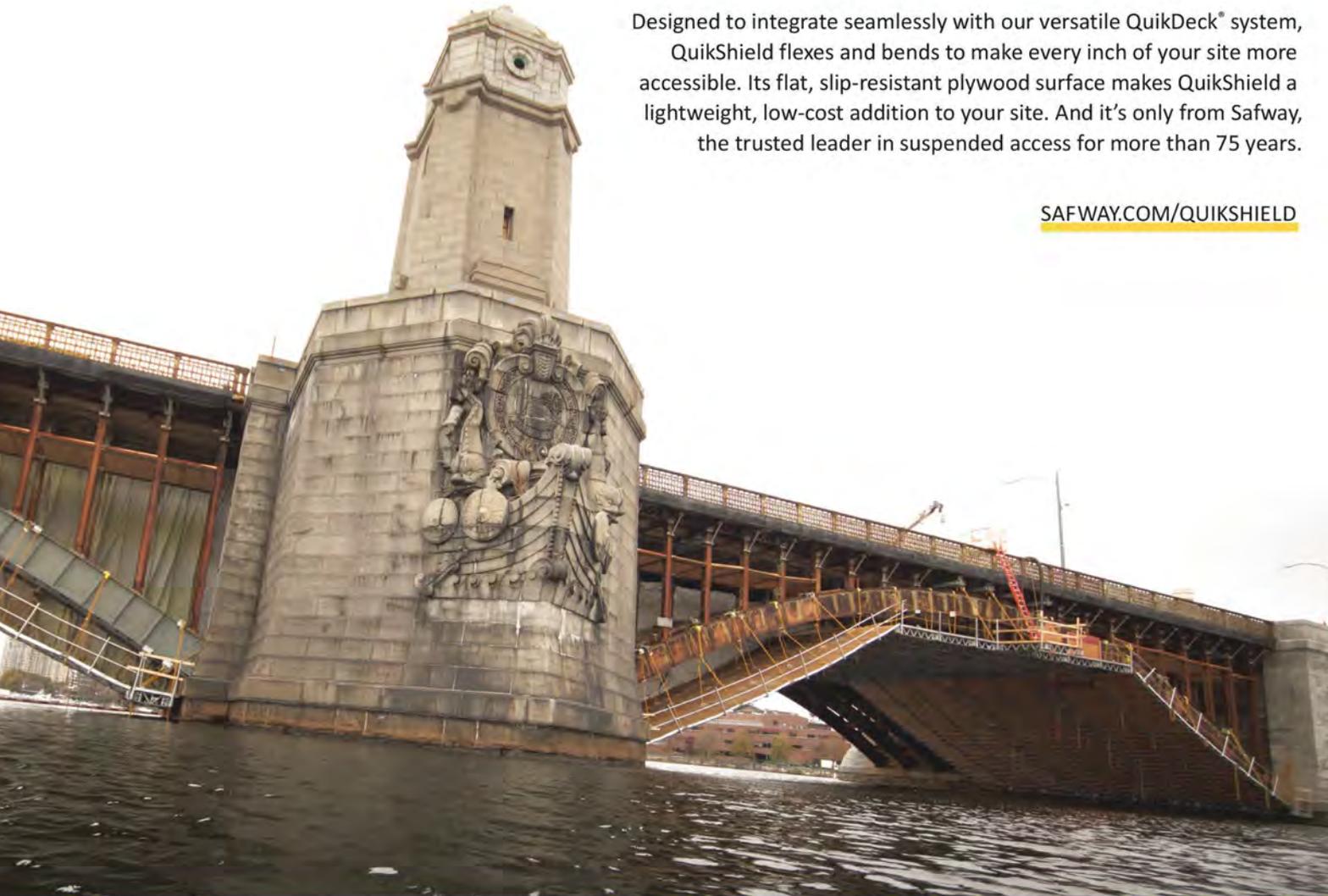
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