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THE CONCRETE BRIDGE MAGAZINE

SUMMER 2017

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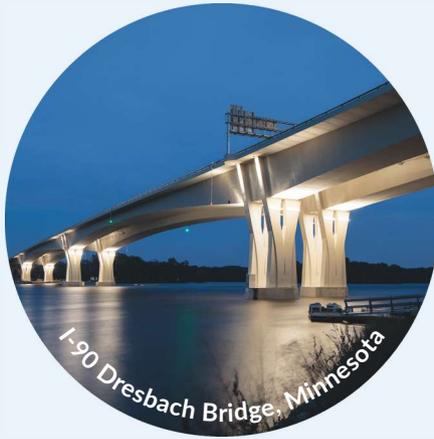
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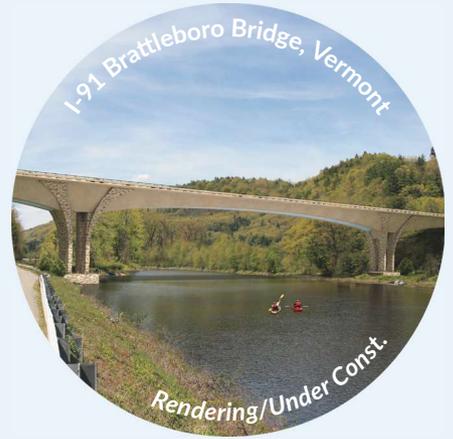


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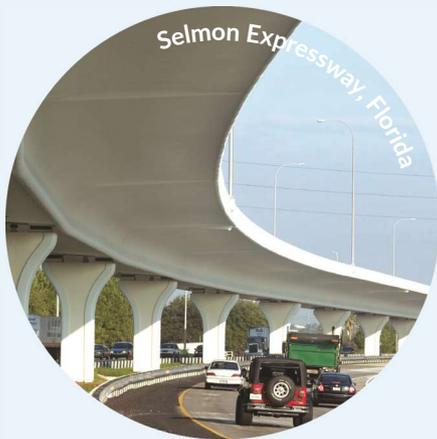




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Photo: HDR.

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Photo: PCI

Looking Down the Organizational Stovepipe

Could the short-term results be obscuring good long-term vision?

William Nickas, *Editor-in-Chief*

Amazing for me to think that this is my 20th editorial on these pages. One of my themes over the years has been to share stories that challenge bridge professionals to expand their thinking about business and professional needs. These messages included topics such as teamwork, staying engaged with the profession, and encouraging them to look into who or what causes change in the industry and our profession. A recent conversation with a former colleague falls under this same theme: how do we encourage employees to be experts but not stunt their professional growth.

My former colleague was urgently searching for qualified concrete design engineers. We discussed how long it takes before their engineers-in-training and young professional engineers “move forward” to become project managers. It usually happens quickly, and we agreed that the time is much too short. Generally, companies need to nurture their young engineers and reward “technocratic growth.” As used here, “technocracy” is a system of management where decision-makers are selected based on technological knowledge and expertise. However, as I thought about the conversation, I realized that the issue at this company was not unique.

Are companies pursuing management practices and/or organizational structures to encourage cross-training early at the expense of more thoroughly developing future subject-matter experts in their fields? Vertical movement within the organization can be a detriment to highly skilled technicians and designers who might otherwise love the technical work they do if they had other opportunities for recognition and reward beyond a move up the corporate ladder.

The Corporate Stovepipe

Word Spy defines stovepipe organization as “An organizational model in which departments, managers, and employees have a narrow and rigid set of responsibilities.” A frequent challenge in these types of organizations is to maintain internal communication across departments. However, in working to maintain or develop good internal communications, extreme care must be exercised to not override or even compete with the development of a strong component of subject-matter experts.

Management expert E.J. Muller said, “One of the first things company executives confronted was the failure of the traditional ‘stovepipe organization’ to generate greater responsiveness to customers. . . That realization led

There are generally five organizational structures: functional, divisional, matrix, team, and network.

Functional—organized by broad business activities—Executive leadership, Finance, Marketing, HR, and Production. Very organized chain of command so that workers can easily communicate within their unit. Interdepartmental coordination and communication suffers.

Divisional—work groups that align according to customers or geography. Some duplicative functions and less efficiency and economy. May cause interdivisional rivalries. Advantage is it serves the customer better.

Matrix—combines divisional into functional. Teams benefit from the expertise of the members while the functional hierarchy evaluates the business activities. Disadvantage is everyone has two bosses.

Team—company operates without chain of command. Virtually flat organizational chart. Without a hierarchy oversight, the risk is employee control. Staff must be trained for broad challenges.

Network—company employs fewer subject-matter experts and relies on a cadre of outside companies to fill business functions.

management to examine ‘pipeline,’ rather than stovepipe, management concepts.” These organizations work to grow leaders through the pipeline and reward employees that identify areas of focused expertise.

The business concept to break down internal stovepipes started as an effort to create better internal communication with the end results focused on customer service. However, it may have, in fact, created a work place environment that diminishes the growth and development of subject-matter experts. We must develop pragmatic, tangible business solutions to avoid the reasons people and organizations drift back to stovepipes, without losing the pipeline to developing our skilled technical experts.

What is your experience with the effective development of technical experts in your company or others you’ve worked for? Are gifted engineers asked to take on too much to enhance their earning potential, to the detriment of the engineering department? Do you agree that we still need the wizards and not everyone needs or wants to be the creative one? I’d appreciate hearing your experiences on this topic.

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Deck placement using Virginia Department of Transportation Class A4 all lightweight concrete with stainless-steel reinforcement. Photo:

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CONCRETE CALENDAR 2017–2019

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

July 11, 2017

FHWA UHPC Implementation Stories Webinar

Register at <http://tinyurl.com/j2hqu7a>

July 24–28, 2017

PCA Professors' Workshop

PCA Campus
Skoki, Ill.

August 2–4, 2017

PTI Level 1 & 2 Bonded PT Field Specialist Training and Certification

Seattle, Wash.

August 6–10, 2017

AASHTO Subcommittee on Materials Annual Meeting

Sheraton Grand Phoenix
Phoenix, Ariz.

August 21–22, 2017

2017 New York City Bridge Conference

New York Marriott East Side
New York, N.Y.

September 6–8, 2017

2017 Western Bridge Engineers' Seminar

Portland Marriott Waterfront
Portland, Ore.

September 13–15, 2017

PTI Level 1 & 2 Bonded PT Field Specialist Training and Certification

Pittsburgh, Pa.

September 17–20, 2017

AREMA 2017 Annual Conference

Indiana Convention Center
Indianapolis, Ind.

October 2–4, 2017

3rd International Symposium on Ultra-High Performance Fibre-Reinforced Concrete

Montpellier, France

October 4–6, 2017

2017 PTI Committee Days

CasaMagna Marriott Cancun Resort
Cancun, Mexico

October 4–7, 2017

PCI Committee Days and Membership Conference

Loews Chicago O'Hare
Rosemont, Ill.

October 15–19, 2017

ACI Fall 2017 Concrete Convention and Exposition

Disneyland Hotel
Anaheim, Calif.

October 24–25, 2017

ASBI 29th Annual Convention

New York Marriott Marquis on Times Square
New York, N.Y.

December 7–8, 2017

2017 National Accelerated Bridge Construction Conference

Hyatt Regency Miami
Miami, Fla.

January 7–11, 2018

Transportation Research Board 97th Annual Meeting

Walter E. Washington Convention Center
Washington, D.C.

February 20–24, 2018

PCI Convention and National Bridge Conference

Colorado Convention Center
Denver, Colo.

April 9, 2018

ASBI 2018 Grouting Certification Training

J.J. Pickle Research Center
Austin, Tex.

June 2–5, 2019

2nd International Interactive Symposium on Ultra-High-Performance Concrete

Hilton Albany
Albany, N.Y.

On page 27 of the Spring 2017 issue of ASPIRE, we incorrectly used the wrong advertisement for LARSA. We regret this error.

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Engineering in Constructability

STV has stayed on the cutting edge of constructible concrete designs through involvement in challenging projects and collaborative approaches that ensure knowledge is shared

by Craig A. Shutt

STV has gained recognition for its expertise with spliced, post-tensioned concrete girders and other long-span concrete designs, and for innovating to meet schedule, cost, and environmental challenges, among others. Today, the firm has spread its influence through partnerships with designers and contractors, and by helping to codify techniques.

"We've been on the cutting edge of improvements and changes to long-span concrete bridges for a long time," says Stu Matthis, vice president of corporate development and facilitator of STV's national bridge practice. Matthis joined the New York-based company in 2005, when his firm, Ralph Whitehead Associates (RWA), was acquired by STV. By adding that company's expertise to STV's own, its reach expanded into the southeast United States from RWA's Charlotte, N.C., base, where Matthis has worked since 1982. (For more on STV's growth, see the sidebar.)

'Contractors come to us once they have won a bid to tap into our expertise and service for enhancing constructability and economics on long-span bridges.'

"Contractors often come to us once they have won a construction bid to tap into our expertise and service for enhancing constructability and economics on long-span bridges," he says. "They also look to us during the design phase for ideas to meet challenges."

The company became involved with spliced-girder concepts in the mid-1980s through Reid Castrodale, who worked on staff for many years (and now serves as managing technical editor for *ASPIRE*SM).

"Reid obtained his PhD and wanted to explore high-tech bridge capabilities. He helped us pursue some major projects and became a technical advisor on many of our concrete projects. We picked up the ball from there." Today, about 60% of the company's bridge work involves concrete designs.

The firm's reputation was enhanced in September 2003 when NCHRP (National Cooperative Highway Research Program) Report 517 (Project 12-57), "Extending Span Ranges of Precast, Prestressed Concrete Girders," was completed by RWA, with technical input from several other experts in the field. "That was a watershed event for us," Matthis says. "It staked our claim to having expertise with spliced girders and being on the cutting edge of improvements and changes in the industry. It put us on the map in that regard."

Railroads Are Key Clients

Many of the firm's innovative designs have been created for railroad clients, a major focus for both STV (passenger) and RWA (freight rail) before the two merged. "We've worked for all the Class I railroads over the years," Matthis says. That work complemented STV's nationwide resume for mass transit projects, including projects for the Massachusetts Bay Transportation Authority, the Chicago Transit Authority, and the New York Metropolitan Transportation Authority. That category remains a solid growth market, he notes.

"We've been able to capitalize on opportunities in the Southeast that didn't exist when we began our transit work. At the time, there were only a

Ironworkers align the couplers for the post-tensioning bars as they set the precast concrete column cap segment at pier 7 for the Roslyn Viaduct. Photo: Renata Magoc.





Speed was the critical component in STV's design for the CSX Transportation railroad bridge in Bay St. Louis, Miss., which was destroyed by Hurricane Katrina in 2005.

Photo: STV.

few lines in the region, such as Atlanta and Miami. Now, we've worked on lines in Charlotte, Raleigh, Hampton, Va., and other areas."

Such work, while typically providing more flexibility for design solutions, presents different challenges than other transportation projects. State departments of transportation (DOTs) often have structured design requirements, including their own manuals and software. Priorities often are different too.

"Railroads are motivated mostly by scheduling and safety, due to their vulnerabilities and the potential nature of accidents. Precast concrete's production schedules and speed of erection are major benefits."

One example where speed was of the essence is the CSX Transportation Railroad Bridge in Bay St. Louis, Miss., which was destroyed by Hurricane Katrina in 2005 (see Spring 2007 *ASPIRE*). With train detours estimated to cost \$1 million per day, CSX needed the 10,050-ft-long structure back online quickly. STV used American Association

American Association of State Highway and Transportation Officials' (AASHTO) Type IV prestressed concrete beams with a cast-in-place concrete deck helped bring the CSX Transportation railroad bridge back into service in only 156 days, before construction had even begun on the highway bridge in the foreground. Photo: STV.

of State Highway and Transportation Officials (AASHTO) Type IV prestressed concrete beams with a cast-in-place concrete deck to restore service in only 156 days, before construction had begun on the adjacent highway bridge. The precast concrete producers delivered about 60 beams per week when construction got underway. "We used as much precast concrete in the design as possible" notes Dan Doty, STV's chief railway bridge engineer.

Speed has become a driving force for bridges of all types. "We're definitely using more accelerated bridge construction [ABC] techniques today," Matthis says. "We're a big supporter of the Every Day Counts program from FHWA [Federal Highway Administration]." Matthis served on an AASHTO/American Council of Engineering Companies/FHWA task



STV's 100+ Years of Experience

STV's oldest predecessor firm, Seelye Stevenson Value & Knecht, was founded in New York, N.Y., in 1912 (as Elwyn E. Seelye & Co.) as a structural engineering firm. Over the years, the firm's disciplines grew to include mechanical, electrical, and civil engineering. Another predecessor firm, Sanders & Thomas, was founded in Pennsylvania in 1945 and performed process and industrial engineering.

In 1968, the combined Sanders & Thomas' companies merged with manufacturer Voss Engineering Co. to form STV Inc., a holding company that ultimately evolved to contain STV Group. Later acquisitions included Lyon Associates (1983), which added international capabilities in several key foreign cities, and STV Environmental and STV Architects, both in 1990.

STV Construction Services was formed in 1994 to undertake design-build contracts, while STV/Silver & Ziskind was added that same year to supply architectural expertise for criminal justice, education, and healthcare facilities. In 2006, STV acquired Ralph Whitehead Associates, a southeast-regional consulting civil and transportation engineering firm.

Today, STV Group is a 100% employee-owned firm and is ranked 20th in *Building Design + Construction's* list of top construction and project management firms and in their Top 10 engineering firms in transit, government, K-12, and multifamily sectors.



The I-85 Yadkin River Veterans Memorial Bridge near Salisbury, N.C., featured dual 2900-ft-long structures. Photo: Aerophoto.

force on ABC, which took a high-level approach to the concept. “Our goal was to streamline environmental permitting and allow construction to begin quicker and be more efficient,” he says. “Permitting is a key part of the scheduling process.”

Permitting often goes faster when bridges can span waterways with fewer piers, he notes, leading to longer concrete spans. “Agencies typically want to avoid water obstructions whenever possible, and DOTs are definitely looking at new ways to complete bridges faster and more economically. Those elements often can be helped by more streamlined permitting.”

ABC aided the design and construction of the U.S. Route 29/70 bridge over the Yadkin River, part of a larger \$140 million design-build project for the North Carolina DOT that replaced deteriorated northbound lanes in a tight, environmentally sensitive area. With the southbound bridge on one side carrying four separate phone/cable lines, and a major overhead transmission line and freight railroad bridge on the other, there was little room to operate.

The new 873-ft-long bridge features seven spans of prestressed concrete bulb-tee girders made continuous for live load. The superstructure was constructed by moving a crane along each span as it was completed, using a top-down approach. “We came up with a concept that wasn’t contemplated in the environmental documentation,” he says. “It assumed you had to get

beside the bridge to build it. We found it would be much quicker to avoid that and work from the top down.”

‘We came up with a concept that wasn’t contemplated in the environmental documentation.’

Another portion of the project, the Interstate 85 (I-85) Yadkin River Veterans Memorial Bridge near Salisbury, N.C., featured dual 2900-ft-long structures with 77-in.-deep prestressed concrete bulb-tee girders (see Winter 2014 *ASPIRE*). These girders, which are from the family of girders developed by the Prestressed Concrete Committee on Economic Fabrication (PCEF), were up to 140 ft long and were also made continuous for live load. Railroad tracks and multiple environmental constraints, including a reservoir with wetlands on each side of the river, severely limited access to the site from the north, west, and east. Prefabrication of components helped alleviate congestion and sped up construction.

Design-Build Growing

The I-85 Yadkin River Veterans Memorial Bridge project was completed via a design-build contract, which has become more popular, Matthis says. “Design-build is becoming more prevalent, as it is schedule-driven. We’re seeing clients using it in return for a faster schedule. They can easily understand how it speeds

up the process by being able to overlap design and construction. Most states are now involved, to some extent.”

The firm often teams with both Flatiron Construction and Lane Construction on such projects, as it did on the I-85 Yadkin River Veterans Memorial Bridge project, especially when precast concrete designs provide the best alternative. “Lane owns a PCI-certified prestressed concrete plant, Prestress of the Carolinas. So when we pursue projects, we can often value-engineer them to precast concrete girders and take advantage of their in-house facility.”

He also has seen public-private partnerships (P3) gaining popularity. “We see more potential for P3 projects, but they place us in a more subordinate role than we are accustomed to serving,” he says. “It’s definitely a different way of working and a different chain of command.”

Another growth market has been inspection and rehabilitation, as bridge owners look to extend their limited funds to add efficiency. “Our inspection services are mostly carried out in the Northeast due to the nature of bridge design,” he explains. “The weather and maintenance needs deteriorate bridges much quicker and more rehabilitation work is required.”

STV provided construction inspection services on the Roslyn Viaduct project on New York Route 25A over Hempstead Harbor in Nassau County, N.Y. The original bridge was determined to be

too deteriorated to renovate, so a new structure, featuring precast concrete haunched box girders, was designed (see Fall 2009 *ASPIRE*).

Stakeholder Input Increasing

With both rehabilitation and replacement projects, gathering and incorporating feedback from all stakeholders has become a key consideration. "People are savvy today and know how to influence designs to suit their needs," Matthis says. Organizations such as the Southern Environmental Law Center influence many designs and bring up issues that must be addressed. "They're concerned that states are building too many infrastructure projects and not paying close enough attention to environmental issues." Such factors create a delicate balance between speeding up projects to reduce user costs and ensuring all environmental concerns are met.

'The level of stakeholder involvement is much higher compared to 20 years ago.'

The firm's engineers often take part in stakeholder-coordination programs through meetings, workshops, online reviews, and other formats. "Feedback

programs have become much more robust, especially on larger projects," he says. "The level of stakeholder involvement is much higher compared to 20 years ago." These programs often are client-driven, he notes. "But if we show we can facilitate them, it's a positive for our consideration in the project. Owners expect this input today and want the team to be sensitive to these needs."

The I-85 Yadkin River Veterans Memorial Bridge, for instance, required input from the owner, local citizens, the U.S. Army Corps of Engineers, North Carolina Division of Water Quality, Duke Energy, Norfolk Southern Railway, North Carolina Railroad, and the Federal Energy Regulatory Commission.

On the Cutting Edge

This range of needs and challenges motivates STV's designers to stay abreast of new developments with concrete materials. "We try to stay on the cutting edge and are always interested in new techniques," Matthis says. "We were one of the first to use lightweight concrete in North Carolina on a routine basis for bridge decks. We expect it will be used in girders soon, too. Any use will benefit where there is a sizable dead load."

Span lengths also will increase, he says. "We're definitely looking to concrete for longer spans. We're



The I-85 Yadkin River Veterans Memorial Bridge was built on a site with multiple environmental constraints, severely limiting access from the north, west, and east. Photo: STV.

already pushing the limits on concrete strength. People chuckle at the notion of 5 ksi today, but that used to be standard. Now, with the addition of materials like fiber reinforcement, post-tensioning techniques, epoxy-coated reinforcement, and corrosion inhibitors, more improvements are possible."

STV also intends to continue to expand via mergers, like the one with RWA, which added new expertise and regional coverage. "We're definitely looking for acquisitions throughout our divisions on an active basis," he says. "We're looking at more all the time." Those mergers will help the company remain on the cutting edge and extend its experience so it can innovate as new challenges arise. 



STV provided construction inspection services on the Roslyn Viaduct project on New York Route 25A over Hempstead Harbor in Nassau County, N.Y. The bridge was replaced with a design featuring precast concrete haunched box girders that reflects the character of the original structure. Photo: Rich Lorenzen.

Refining the Adjusted-Score Design-Build Process

Through its design-build process, the Florida Department of Transportation seeks to provide continuous improvement for both its projects and the process itself

by Thomas A. Andres, Florida Department of Transportation



Florida Department of Transportation's J. Turner Boulevard/Interstate 95 design-build project features a curved, spliced U-girder structure. Photo: Florida Department of Transportation.

The Florida Department of Transportation (FDOT) has encouraged the use of design-build delivery methods since the late 1980s, and the process continues to improve as designers, contractors, and the Department gain experience. FDOT has procured more than 475 design-build projects with total contract amounts of more than \$13.5 billion. Currently, more than 70 projects are underway, totaling more than \$5.5 billion. The program has proven successful at encouraging innovation through a fair, competitive process that strives to meet or exceed project expectations while providing a high level of transparency.

Increasingly, FDOT realized that the design-build format meant it didn't need to have all the solutions to transportation problems. FDOT quickly witnessed the power of mobilizing hundreds of minds to focus on developing the best comprehensive solution to a complex transportation problem through a competitive process.



Precast concrete pile cap on Escambia Bay Interstate 10 design-build project. Photo: WSP.

Design-build projects create innovation by bringing the contractor's expertise into the design process up front to maximize efficiencies. These can include customizing the solution based on available equipment, workforce talents, and supplier availability and expertise. The contractor typically looks to optimize production rates by separating the work from the traffic and reordering the sequence of construction for added efficiency. The contractor's perspective serves to challenge designers and past norms.

For design-build projects to continue to be successful, the process has to be dynamic and evolving. Project solutions improve over time based on lessons learned. Ideally, the bar rises for each successive project.

Developing Design Criteria

For the most part, design criteria do not change from project to project for a given work mix, but design-build criteria may differ from those for a conventional project. FDOT's governing regulations (such as design manuals) have been developed for each delivery method. Design manuals include separate boxes within the text that amend certain design requirements specifically for design-build projects.

Industry feedback is encouraged prior to the start of the project's procurement process. Most large projects include an Industry Forum, which occurs prior to the advertisement. The Industry Forum allows the project to be presented by FDOT and provides final teaming/networking opportunities for both contractors and consultants.

The draft request for proposal (RFP) is posted prior to the Industry Forum. Teams are encouraged to meet with FDOT management in one-on-one meetings to introduce team members and provide feedback on the project and the RFP. With the goal of gaining feedback to improve the RFP to better meet project objectives, FDOT typically asks all the teams the same questions.

Once the procurement process starts (by posting the project advertisement), a "veil of silence" descends on FDOT and the teams pursuing the project. Except for the prescribed one-on-one meetings, all communications cease, although questions and responses may be posted on a website-based platform to be viewed by all teams.

Encouraging Competition

FDOT's design-build program was initially fairly rigid, with a shortlist of approved contractors selected according to experience and other factors. This precluded some qualified companies that could have generated successful concepts. To encourage more competition, the process was revised to create a two-tiered grading system that allows any team to participate in the opening phase and be judged on its merits. The only caveats are that a consultant involved in writing the RFP cannot pursue the project, and that each team has to meet certain work-type qualifications based on the work mix.

FDOT first evaluates the letters of interest (LOIs), typically worth 20 of the project's 100-point total score. It focuses on the

qualifications and experience of both the design-build firm and its key team members. The LOI also includes the team's understanding of the project and its general approach. Based on a team's LOI score relative to other teams' scores, each team decides whether to proceed to the technical proposal phase.

Next, the teams prepare and submit technical proposals. FDOT scores each technical proposal, which is typically worth the remaining 80 points of the total project score. The technical proposal presents the team's design with sufficient information to enable the Department to further evaluate the proposer's solution. A stipend is usually provided to the two top non-winning teams that submit a technical proposal meeting all RFP requirements.

Process Promotes Innovation

With the objective of providing better solutions at lower costs, FDOT uses an alternative technical concept (ATC) process, which allows teams to develop concepts and manage risks that FDOT would assume to be unrealistic on a conventional design-bid-build project. Any deviation from the RFP is by definition an ATC. A proposed ATC must provide an approach equal to or better than the RFP requirements, with no reduction in scope, quality, performance, or reliability. The ATCs are kept confidential prior to the final selection.

In the past, FDOT tended to amend the RFP based on an approved ATC. That made it difficult to draft RFP language that allowed an ATC without giving the idea to the other teams. The current trend is to amend the RFP only for approved ATCs that change the fundamental rules of the game, such as ATCs that introduce design exceptions (violate AASHTO criteria) or ATCs that reduce project scope.

The design-build process has been criticized by some owners for providing less control compared with conventional design-bid-build projects, resulting in a final solution that does not meet expectations. FDOT has overcome this by intentionally writing certain aspects of the RFP rigidly. This allows ideas to be vetted through the ATC process. For example:

- Concept plans are attached to the RFP as a reference document, and therefore are "for information only" and not a requirement. For instance, if the RFP states that the horizontal and vertical alignments shall be "per the concept plans ± 5 ft," the proposer must show



Rendering of Pensacola Bay Bridge low-level single-piece precast concrete piers. Photo: WSP.

through the ATC process that its ATC solution (interchange reconfiguration, for example) is equal to or better than the RFP requirements.

- An ATC also is required for design concepts, components, elements, details, or construction techniques not normally used by FDOT. The bottom line is to promote new ideas and innovation but ensure the details are well executed.

Contractors are sometimes frustrated by this ATC vetting step, but they are happy FDOT is open-minded and willing to work through the issues with them, reducing risk on both sides.

One-on-one ATC meetings are held to allow teams to describe their proposed alterations and their benefits. The lists of proposed ATCs are sent to FDOT prior to the meeting to ensure the proper FDOT personnel attend the meeting to respond to the proposed ideas.

For a large project, two to three one-on-one ATC meetings with each team may be necessary. On many projects, informal, draft-written ATC submittals are encouraged so FDOT staff (gatekeepers) can offer draft responses between meetings. This early and consistent feedback allows the teams to better understand FDOT's intentions and expectations and is focused on achieving an ATC that will eventually be approved by FDOT.

FDOT has approved thousands of ATCs on hundreds of design-build projects, resulting in hundreds of millions of dollars in savings, shorter construction times, and added value.

Scoring Factors

Technical review committee (TRC) members provide the technical scores based on the information presented in the LOIs. They also provide the technical scores based on the information presented in the technical proposals. As part of the "veil of silence," each TRC member works independently of other TRC members to review LOIs and technical proposals.

FDOT strives to use TRC members with diverse backgrounds to cover the project's work mix. TRC members are FDOT

employees and are typically assisted by technical experts on complex projects. Technical experts are available throughout the process to answer questions outside of the TRC members' expertise.

The members provide technical scores for all aspects of the project listed in the RFP evaluation criteria; the scores are then averaged and the best-value formula is applied. The best-value determination is the team's price divided by its technical score, with the team with the lowest number being the winner.

It is important for the RFP to be customized to provide an appropriate breakdown in technical score points to achieve an acceptable outcome. What is important on an urban interchange project in south Florida may be quite different from a rural project in north Florida.



Precast concrete bent cap being erected on SR 83 (US 331) over Choctawhatchee Bay. Photo: WSP.

Summary

Experience has shown that doing design-build well is hard work for both the owner and the proposers. But its results are worth the effort.

FDOT continues to learn from the competitive design-build process to achieve the goal of establishing better ways to construct transportation facilities. Conventional projects also continue to get better as FDOT incorporates solutions based on lessons learned from design-build projects. 

Thomas A. Andres is the assistant state structures design engineer in the Florida Department of Transportation in Tallahassee, Fla.

PROJECT

ROUTE 198 (DUTTON ROAD) OVER HARPER CREEK

STAGED SUPERSTRUCTURE REPLACEMENT USING LIGHTWEIGHT CONCRETE AIDS PROJECT GOALS

by Jeremy Schlusel, Caroline Hemp, and Timothy Beavers,
Whitman, Requardt & Associates LLP

When the Virginia Department of Transportation (VDOT) selected the bridge carrying Route 198 (Dutton Road) over Harper Creek for a superstructure replacement, many challenges had to be resolved. VDOT desired to widen the superstructure on this important rural primary route while minimizing the impact on nearby sensitive brackish-water wetlands.

These challenges led the design team to investigate the reuse of the original gravity-style abutments on timber piles. To reuse the substructure, the dead load of the replacement superstructure had

to be less than or equal to that of the existing superstructure. Additionally, one lane of traffic was required to remain open during construction, which resulted in a tight working area for the contractor.

With all of these issues in mind, the design team concluded that the most efficient solution would be a staged superstructure replacement using lightweight concrete for both the prestressed bulb-tee beams and cast-in-place deck. Sheet-pile walls were used to accommodate the minor widening of the approach roadway, minimizing impact on the wetlands. All details and

material selections for this bridge met VDOT's goal of reducing long-term maintenance.

Project History

Existing Bridge

The bridge carrying Route 198 (Dutton Road) over Harper Creek is located in Gloucester County, Va., in VDOT's Fredericksburg District. Completed in 1941, it was part of the realignment of the original roadway to improve poor roadway geometry. The bridge structure consisted of one 40-ft simple span for a total length of 42 ft 6 in. (end-of-slab



Aerial view of the new bridge and approach roadway on Route 198 in Gloucester County, Va. Photo: Whitman, Requardt & Associates.

profile

ROUTE 198 (DUTTON ROAD) OVER HARPER CREEK / GLOUCESTER COUNTY, VIRGINIA

BRIDGE DESIGN ENGINEER: Whitman, Requardt & Associates LLP, Richmond, Va.

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

PRECASTER: Atlantic Metrocast Inc., Portsmouth, Va.—a PCI-certified producer

SURVEYOR: NXL Construction Services Inc., Richmond, Va.

to end-of-slab) and was on a tangent alignment with a 0% gradient.

The superstructure was 27 ft 4 in. wide (out-to-out), which included a roadway width of 24 ft from curb to curb and a 1-ft 8-in. combination curb/concrete rail. The superstructure consisted of four haunched cast-in-place reinforced concrete T-beams with a reinforced concrete deck, which was placed integrally with the T-beams. The reinforced concrete deck had an asphalt overlay of approximately 2½ in. The existing superstructure did not have bearing pads, per the original plans.

The bridge substructure units are parallel to each other and perpendicular to the centerline. The abutments are concrete gravity-style with minimal reinforcement supported on timber piles approximately 35 ft in length. Connecting the two abutments are three reinforced concrete struts below the waterline. The wingwalls are oriented 45 degrees to the backwall.

Need for Rehabilitation

In 2011 the bridge structure was identified as requiring maintenance. The bridge safety report revealed the general condition of the existing concrete deck to be structurally deficient due to delaminations up to 2½ in. deep throughout the concrete deck, with the bottom of the deck also having delaminations and cracks. In addition, the concrete slab overhangs and railings had delaminated and spalled, exposing corroded reinforcing steel. It was also noted that the exterior beams had cracks, delaminations, and spalls along the sides and bottoms. After preliminary discussions with VDOT, a full bridge replacement was determined not to be a viable option due to its location within existing wetlands and the necessary permits required for such an extensive project. VDOT concluded that the most appropriate solution to rehabilitate

the 70-year-old bridge structure was a superstructure replacement.

An in-depth field investigation of the existing substructure was conducted to determine its condition and suitability to support the new superstructure. All of the visible concrete on the abutments was hammer sounded to record areas of delaminated and spalled concrete. A probing rod was used to determine the extent of features that were under water, such as the concrete struts.

Design Aspects

Various superstructure replacement options were evaluated, including prestressed hollow-core slabs with a reinforced concrete deck, VDOT precast concrete bulb-tee beams with a reinforced concrete deck, and galvanized structural steel girders with a reinforced concrete deck. To determine the most appropriate solution, several factors were evaluated, including geometry, final conditions, maintenance of traffic, environmental issues, and structural design. Ultimately, the final decision centered on which option would not increase the dead load applied to the existing abutments while providing the best long-term, low-maintenance solution.

The VDOT concrete bulb-tee beams met the geometric requirements and provided a much more durable option than a structural steel superstructure.

Two 29-in.-deep lightweight concrete bulb tees prior to deck placement. Photo: Virginia Department of Transportation.

While the structural steel option did offer the most lightweight superstructure, it was determined not to be an appropriate long-term, low-maintenance solution for this location due to its proximity to the brackish water. The use of the hollow-core slabs per VDOT design guidelines would have required a reinforced concrete deck for this roadway classification. While this solution was efficient, the geometry and high dead load for this option did not meet the requirements for using the existing substructure.

The VDOT concrete bulb-tee beams met the geometric requirements and provided a much more durable option than a structural steel superstructure in this tidal environment, but the use of normalweight concrete increased the dead load on the existing substructure.

Therefore, to minimize the dead load, the designers evaluated the use of various densities of lightweight concretes for both the bulb tees and the concrete deck. After discussions with VDOT and industry professionals, the bulb tees were designed using VDOT Class A5 lightweight concrete with a maximum density of 115 lb/ft³ and a minimum compressive strength at 28 days of 5 ksi. The beams were designed for a minimum compressive strength



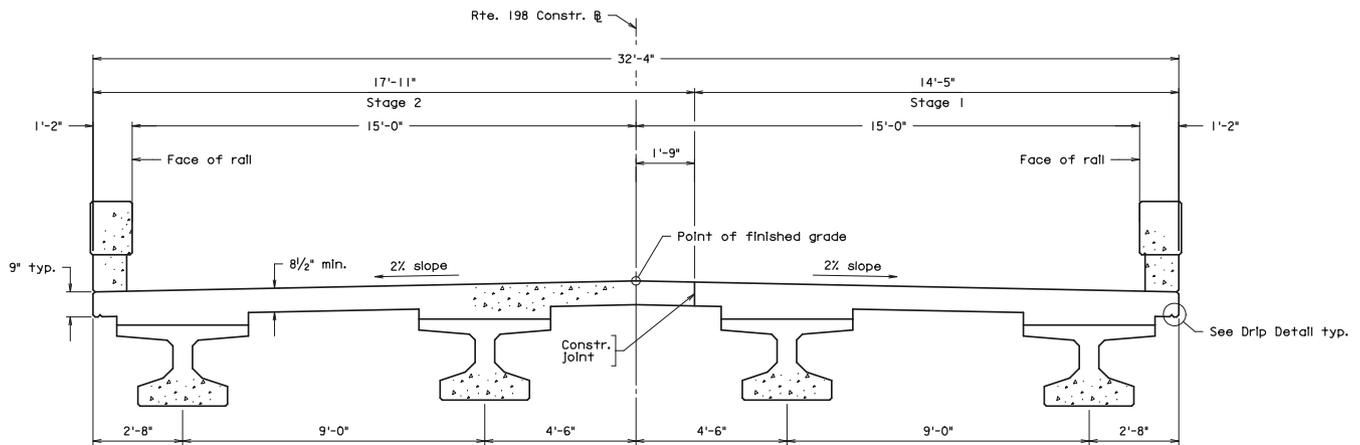
VIRGINIA DEPARTMENT OF TRANSPORTATION, FREDERICKSBURG DISTRICT, OWNER

BRIDGE DESCRIPTION: A 45-ft 2-in.-long, lightweight concrete prestressed bulb-tee beam bridge

OTHER MATERIAL SUPPLIERS: Lightweight aggregate supplier: Carolina Stalite Co., Gold Hill, N.C.; Stainless-steel reinforcement supplier: SteelCON Supply Company, Jacksonville, Fla.

STRUCTURAL COMPONENTS: Four lightweight concrete prestressed 29-in.-deep bulb-tee beams with an 8½-in.-thick cast-in-place lightweight concrete deck and a lightweight concrete semi-integral backwall and substructure modifications

BRIDGE CONSTRUCTION COST: \$526,880 (\$360.78/ft²)



Transverse section of new superstructure showing staged construction. Figure: Whitman, Requardt & Associates.

at the time of transfer of 4 ksi. The deck, semi-integral backwalls, parapets, and substructure modifications were designed using VDOT Class A4 lightweight concrete with a maximum density of 105 lb/ft³.

To reach these lower densities, the concrete mixture proportions for the beams required the use of lightweight coarse aggregates, while the concrete deck contained both lightweight coarse and fine aggregates. Fly ash and silica fume were also incorporated into the beam concrete mixture proportions. The only pozzolan included in the deck concrete was fly ash.

The concrete test results indicated permeability values of less than 900 coulombs for the reinforced deck concrete. According to ASTM C1202, these results correspond to a “very low” permeability. This added benefit of the lightweight concrete will provide protection to the reinforcing steel from chloride attack. Low-permeability concrete will, in turn, contribute to the long-term low-maintenance of the structure. Tests on the beams’ concrete revealed another benefit: although the design required a 28-day compressive strength of 5 ksi, on average the concrete of the beams had compressive strengths between 8 and 9 ksi at 28 days.

In addition to the lightweight concretes, corrosion-resistant reinforcing steel was used throughout the project, following VDOT design procedures. The mild reinforcing steel located in the bulb tees and substructure modifications was designated as Class I (ASTM A1035, low-carbon/Chromium reinforcing steel) and the reinforcing steel located in the superstructure, including the semi-

integral backwall, was designated as Class II (stainless-steel clad deformed). However, because these bars are not domestically produced, the project used Class III (ASTM A955, solid stainless-steel) bars for concrete reinforcement.

The new superstructure configuration is 45 ft 2 in. from end-of-slab to end-of-slab and 32 ft 4 in. out-to-out of parapet. The bridge maintains the same horizontal alignment, and the vertical gradient was modified to be approximately 0.3% to ensure drainage. The final cross section consists of four 29-in.-deep prestressed, lightweight concrete bulb-tee beams spaced at 9 ft with an 8 1/2-in.-thick concrete deck. The bridge has a final curb-to-curb width of 30 ft, which provides two 12-ft-wide lanes with 3-ft-wide shoulders. An open-curbed, Kansas corral-type parapet was chosen to facilitate deck drainage and semi-integral backwalls were detailed at each end of the superstructure to make it a jointless structure. The existing abutments and wingwalls were modified to support the new superstructure width and bearing pad elevations.

In addition to the superstructure constraints, the project needed to accommodate the wider superstructure with only minor widening of the approach roadway. To achieve this widening without impacting the designated wetlands, marine-grade sheet-pile walls were designed and constructed. The sheet piles facilitated the approach roadway widening and grading that was necessary along the shoulders. The widening also slightly increased the work space for the contractor and enabled the project to maintain 11-ft lanes for the duration of the project.

Construction Sequencing

To facilitate reconstruction of the bridge structure and to maintain traffic, staged-construction methods were used for this project. This consisted of permanent single-lane closures and maintaining one lane of traffic with temporary signals. To shift traffic, the existing shoulders required upgrading to accommodate traffic for a period of time. Due to the geometry of the bridge superstructure, the minimum lane width was only 11 ft from curb to curb, requiring a detour for over-width vehicles.

Construction

In general, the construction of this project went smoothly. After discussions with the contractor, the only issue mentioned, besides the tight working constraints, involved the placement of the lightweight concrete bridge deck. The concrete was difficult to finish because of its sticky nature; the exact cause of this texture was undetermined. After experimenting with different types of trowels for finishing, the contractor noted a granular texture was left on the surface of the deck. This did not affect the final product because the concrete deck was grooved upon completion.

In addition to the challenges of finishing the deck, it was noted that the lightweight concrete in the deck took longer than usual to reach 28-day strength. This did not affect the schedule for this project; however, the contractor indicated that it could have caused a delay if the bridge had been larger. 

Jeremy Schlüssel is vice president, Caroline Hemp is a design engineer, and Timothy Beavers is an associate at Whitman, Requardt & Associates LLP in Richmond, Va.

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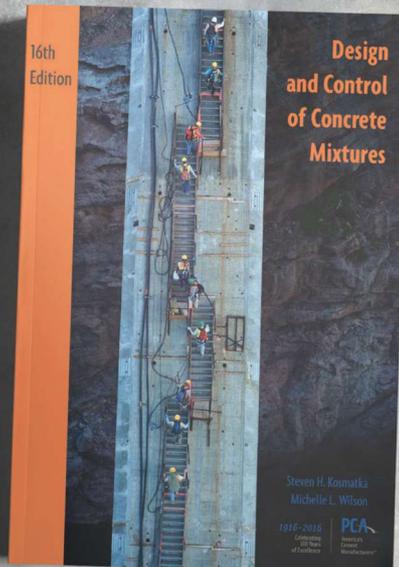
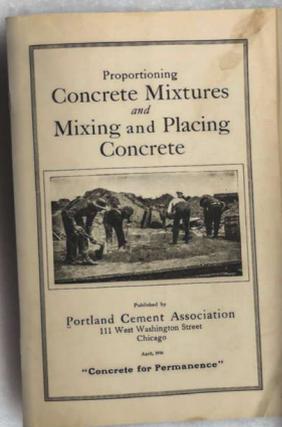


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PROJECT

EL SALTO FALLS STREET BRIDGE

HIGH-PERFORMANCE PRECAST CONCRETE IS KEY TO COST-EFFECTIVE ENVIRONMENTAL IMPACT AVOIDANCE

by Dr. Jay Holombo and Wade Durant, T.Y. Lin International,
and Jon Grafton, Oldcastle Precast

An innovative bridge design using high-performance precast, prestressed concrete allowed construction to proceed without entering a 170-ft-wide environmentally sensitive area (ESA) at the bottom of a creek, thus meeting resource agency permit requirements. In addition, access to the bottom of the creek was limited to a 90-ft-wide construction easement. This design was developed using a collaborative approach among the design team, the owner, the precast concrete producer, the contractor, and the city. This collaborative approach continued through the construction phase to deliver this challenging project with great success.



Background

Construction of a new community, appropriately named The Preserve, is underway in the coastal city of Carlsbad, Calif. Bisecting this community is Buena Vista Creek, which is now spanned by the newly constructed El Salto Falls Street Bridge. This bridge carries two traffic lanes, two bicycle lanes, and two sidewalks, as well as two 12-in.-diameter potable water lines, a 6-in.-diameter recycled water line, and a 12-in.-diameter gravity sewer line below the deck. The sewer line had to be operational before property sales within the community could begin, which placed it and the supporting bridge on the critical path of the project. Upon

Aerial photo shows the newly constructed El Salto Falls Street Bridge in relation to the environmentally sensitive area (ESA) within Buena Vista Creek, as denoted by the orange fence. Under the bridge, the ESA is 170 ft wide at the bottom of the creek. All Photos and Illustrations: T.Y. Lin International.

completion of all improvements within the community, the city of Carlsbad will take over ownership and maintenance responsibilities of the infrastructure from Cornerstone Communities, the developer.

Buena Vista Creek and the adjacent open space is an environmentally sensitive riparian habitat; just outside of the community is El Salto Falls, a formally designated Native American Sacred Site. To avoid a lengthy permit

process with the U.S. Army Corps of Engineers, the owner required the bridge to be constructed without entering the 170-ft-wide ESA at the bottom of Buena Vista Creek. Furthermore, the contractor was required to stay within the 90-ft-wide easement when accessing the creek from the top of the banks.

Design

The design team considered several options that allowed construction without

profile

EL SALTO FALLS STREET BRIDGE / CARLSBAD, CALIFORNIA

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: T.Y. Lin International, San Diego, Calif.

PRECAST SPECIALTY ENGINEER AND PRECASTER: Oldcastle Precast, Perris, Calif.—a PCI-certified producer

ENVIRONMENTAL DOCUMENTATION: HDR Inc., San Diego, Calif.

CONTRACTORS SPECIALTY ENGINEER: D.H. Charles Engineering Inc., Cardiff, Calif.

PRIME CONTRACTOR: LB Civil Construction, Escondido, Calif.

POST-TENSIONING CONTRACTOR: Dywidag Systems International (DSI), Long Beach, Calif.

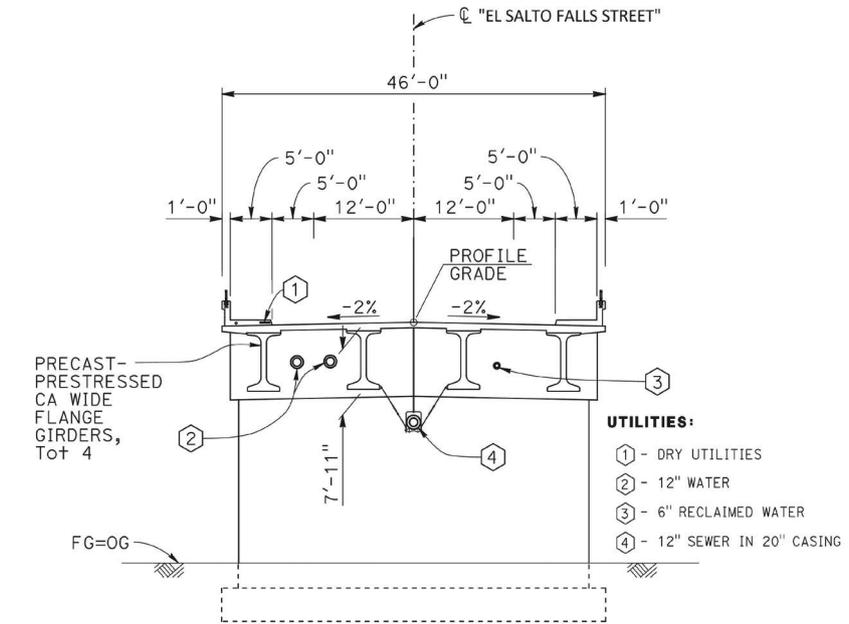
GIRDER ERECTION: Maxim Crane Works, San Diego, Calif.

entering the ESA. These included steel girder, steel truss, and high-performance precast concrete options. Long lead times and estimated higher costs precluded steel alternatives. Inspired by the *ASPIRE*SM Winter 2008 article "Precast Enables Total Environmental Avoidance" about the Daggett Road Bridge, the design team selected a high-performance precast concrete spliced-girder bridge option, where the center span girder segments are erected from previously constructed end spans.

Measuring 288.6 ft in length, the bridge has end spans of 52.8 ft and a center span of 183 ft. The concrete deck is 46 ft wide and is supported by four 84-in.-deep California wide-flange girders. The girders use high-performance concrete with a 28-day design compressive strength of 9 ksi to meet the high flexure and shear demands from the large crane loads during erection operations. Spanning between the girder flanges are 3.5-in.-thick precast, prestressed concrete deck panels, which facilitate the connection details of the hangers used to support water and sewer lines. Furthermore, these precast concrete deck panels allowed utility installation and deck construction to occur simultaneously.

Precast concrete deck panels allowed utility installation and deck construction to occur simultaneously.

The end-segment girders run continuously from the abutments and terminate 29 ft beyond the centerline of the adjacent piers. Closing the gap are 121-ft-long midspan girder segments with 2-ft-long cast-in-place concrete closures. Full-length post-tensioning tendons provide continuity of the superstructure.



The bridge utilizes 12 high-performance precast, prestressed concrete girder segments connected with cast-in-place splices and continuous post-tensioning. The deck is comprised of 3.5-in.-thick stay-in-place precast, prestressed concrete deck panels that span between the girders and a cast-in-place reinforced concrete topping.

The substructure consists of integrally connected pier walls and abutments supported by spread footings on the south side of the creek and a pile cap with drilled-hole, cast-in-place pile foundations on the north side. To minimize the width of the footing and proximity to the ESA boundary, the pier walls are pinned to their footings with a single row of reinforcement.

The integrally connected abutment diaphragms are relatively massive, with depths exceeding 18 ft and a thickness of 5 ft. These elements served as counterweights during erection of the center span girder segments. To accommodate thermal, post-tensioning, and shrinkage movements, the abutment diaphragms were designed to translate relative to the supporting footings.

Construction Sequence

Developing a cost-effective construction sequence prior to bid and award was one of the most significant challenges of the project. The construction sequence assumed during the design process was that the foundations, substructures, and superstructure were to be constructed to the moment inflection points of the center span. An initial stage of post-tensioning would then be applied to the deck to limit stresses during erection of the center span girder segments. The deck post-tensioning consisted of two tendons with four 0.6-in.-diameter strands in the build-up regions above each girder flange.

The initial design assumed that 300-ton conventional track-mounted cranes would be centered over the piers to erect the center span girder segments.

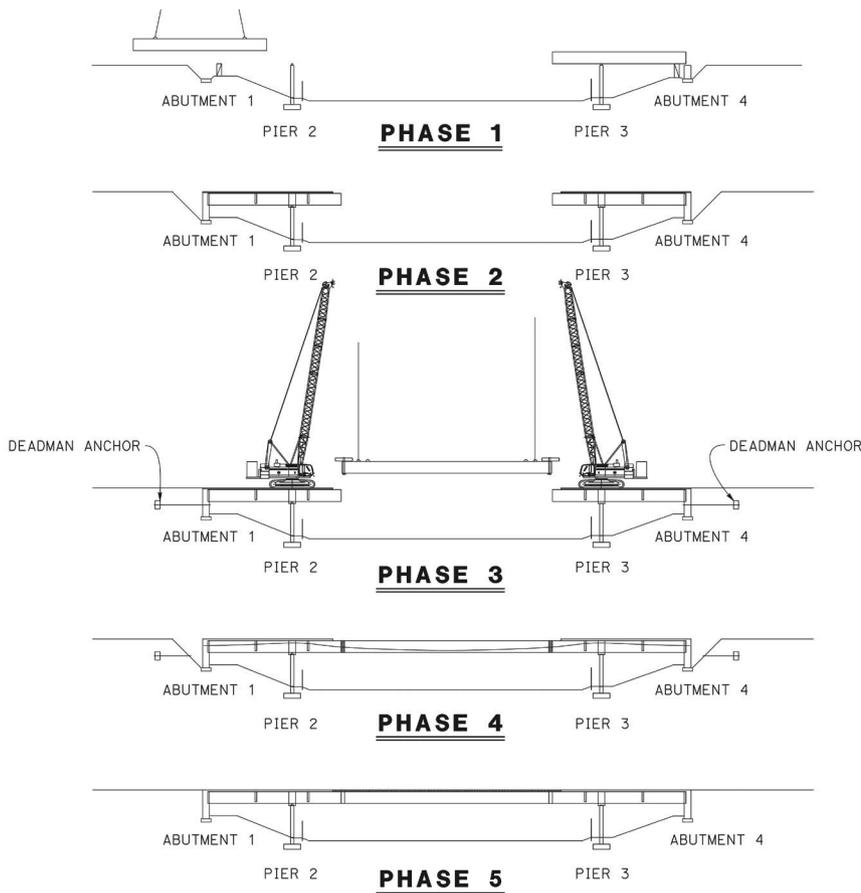
CORNERSTONE COMMUNITIES/CITY OF CARLSBAD, OWNER

BRIDGE DESCRIPTION: Three-span continuous precast, prestressed concrete spliced-girder bridge

STRUCTURAL COMPONENTS: Four 84-in.-deep by 288-ft-long precast, prestressed concrete California wide-flange girders (cast in segment lengths of 121 ft and 78 ft). One hundred and five precast, prestressed concrete deck panels with cast-in-place concrete topping slab. Concrete pier walls and abutment diaphragms are integrally connected to the superstructure.

BRIDGE CONSTRUCTION COST: \$4,400,000 (\$332/ft²) not including wet utilities

AWARDS: "2016 Project Achievement Award for Projects under \$17 million," CMAA San Diego Chapter; "2016 Outstanding Project Award," APWA San Diego and Imperial Chapter



Development of the multiphase construction sequence was a collaborative effort by the contractor, design engineer, precaster, and owner. The erection plan was revised to use a track-mounted crane and a truck-mounted crane.

Fully assembled, each crane weighs 640,000 lb, compared to the notional design truck (HL-93), which weighs 72,000 lb. The combined weight of the track-mounted crane and the supported girder equaled the weight of span 3 and the cantilever bridge deck and girders. Crane loads were the controlling load case for the shear reinforcement near the piers. Pretensioning strands at both the top and bottom of the girder controlled stresses during transport, erection, and subsequent deck construction. Girder post-tensioning provides continuity and load resistance of the completed bridge.

A key assumption was that the cranes would be fully assembled prior to driving onto the newly completed end spans of the bridge. Consequently, significant lateral surcharge pressures on the tall abutment diaphragms were anticipated when the cranes

traveled over the bridge approaches. It was also assumed that these lateral surcharge pressures would be resisted with deadman anchors that would be subsequently removed in later phases of the construction process.

The construction sequence shown in the project plans was schematic, with the intention of demonstrating feasibility and illustrating project constraints. The bid documents required the contractor to develop their own construction sequence, submit working drawings, and prepare supporting calculations demonstrating that the load-carrying capacity of the partially completed structure would not be exceeded during crane setup and girder erection operations, per the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*.

Crane loads were the controlling load case for the shear reinforcement near the piers. Pretensioning strands at both the top and bottom of the girder controlled stresses during transport, erection, and subsequent deck construction. Girder post-tensioning provides continuity and load resistance of the completed bridge.

Construction

Managing submittals was a key challenge for the contractor, the owner, and the resident engineer. Documents related to construction sequence, crane loading, shoring, and pile placement were submitted and reviewed, as a first order of work. Shop drawings of the precast concrete elements were complicated because hardware embedded in the girders and the precast concrete deck panels had to line up with the utility hangers. As a result, each precast concrete girder segment and deck panel was unique, and therefore had to be labeled, tracked, and stored in a specific order to facilitate placement.

Construction proceeded according to the assumed construction sequence, in which spans 1 and 3 were constructed to create platforms for constructing the center girder segments in span 2. After the concrete for the span 1 and span 3 bridge decks was placed, the deadman anchors were attached to the abutment diaphragms and the approaches were backfilled to allow the cranes to move onto the bridge deck.

The contractor then erected the center girder segments with notable differences to the construction sequence shown in the contract documents:

1. At the southern approach, each girder segment was backed onto span 3 with one end supported by the truck and the other end supported by the 300-ton track-mounted crane centered over pier 3.
2. Both ends of the girder segment were placed on timber blocking,



where strongback brackets were attached to the ends. Upon erection, these brackets temporarily supported the center girder segments and the closure concrete until the continuous post-tensioning was applied.

3. After attaching the leads to both ends of the girder segment, the track-mounted crane lifted the girder segment over the creek.
4. Leads from a 500-ton truck-mounted hydraulic crane centered over pier 2 were then attached to the north end of the girder segment. Load was released from the 300-ton crane as the south end was lowered onto timber blocking near pier 3.
5. The leads from the 300-ton crane were then attached to the south end, which allowed the girder segment to be positioned and lowered into place with both cranes.

The contractor's choice of erecting the center segments with only one 300-ton track-mounted crane significantly reduced set-up time and cost. Analysis from the contractor's specialty engineer demonstrated that additional shear reinforcement in these girder segments was required in a critical location as a result of this choice.

Closure-pour concrete and subsequent post-tensioning were completed prior to construction of the deck in the center of span 2. Unconvinced by the designer's



The load from the girder end is transferred from the track-mounted crane (red) at pier 3 to the hydraulic crane (yellow) at pier 2. A 2-in.-thick layer of sand protected the deck surface from the tracks of the crane.



Phase 1 construction included placement of end girder on shoring towers at the abutments and timber blocks on the piers. The end girders cantilever 29 ft past the pier and extend over the environmentally sensitive area.

claim that the girders would not buckle during post-tensioning operations, the contractor installed timber bracing and metal straps at frequent intervals along the unsupported length of the girders. The bracing and straps were removed after deck placement.

Rolling platforms supported by the bottom flanges of the girders were used to install the suspended wet utility lines without entering the ESA. Installation, testing, and in-service use of the gravity sewer line were completed on time to allow the subsequent phases of the project to proceed on schedule.

Summary

The design team faced the significant challenge of developing a cost-effective design that could be constructed without entering the 170-ft-wide ESA,

within a tight schedule and with limited access. An innovative design using high-performance precast, prestressed concrete girders was developed based on a collaborative effort of the design team, the owner, the precast concrete producer, and the city. This collaborative approach continued into the construction phase, where the contractor further refined the concept with an alternative crane setup and erection plan for the center girder segments. The resulting bridge was delivered on time and with great success. ▲

Dr. Jay Holombo is a senior project manager and Wade Durant is a senior bridge engineer, both with T.Y. Lin International in San Diego, Calif. Jon Grafton is the western region business development manager of Oldcastle Precast in Perris, Calif.



After transfer, both cranes supported the center girder segment and lowered it into position. Once in place, strongback brackets temporarily supported the center segment until the closure-pour concrete attained sufficient strength and continuous post-tensioning was applied. Each center girder segment weighed 80 tons.

BAYONNE BRIDGE

NEW BRIDGE ALLOWS LARGER CONTAINER SHIPS TO PASS

by Joseph LoBuono and Chester Werts, HDR



Tight constraints for erection of single-cell box-girder pier table segment. The 42-ft difference in the elevations of the old and new approaches is evident. All Photos and Figures: HDR.

The Port Authority of New York & New Jersey's (PANYNJ's) Bayonne Bridge carries Route 440 over the Kill Van Kull, the navigational entrance to the Ports of Newark and Elizabeth in New Jersey. The Bayonne Bridge connects the city of Bayonne, N.J., to the north with Port Richmond, N.Y., in New York City's Borough of Staten Island, to the south. Prior to reconstruction, the average daily traffic across the bridge was approximately 22,000 vehicles. Bids for the "Bayonne Bridge Replacement of Main Span Roadway and Approach Structures" contract were received in April 2013 and the construction contract was awarded on May 10, 2013, in the amount of \$744 million.

Following the widening and deepening of the Panama Canal, including a third set of locks, and the advent of larger post-Panamax container ships, the restrictive 151-ft navigational clearance (air draft) of the Kill Van Kull would have resulted in container traffic seeking other ports of call. In addition, there have been frequent incidents of container ships' masts scraping the underside of the existing bridge structure. These issues created the need to increase the air draft of the Bayonne Bridge to maintain the ports' economic competitiveness, protect port-related jobs, maintain regional economic activities, and provide a safer bridge crossing for the traveling public.

The port facilities of Newark and Elizabeth are among the busiest in the world, with approximately 12% of all U.S.-bound international containers passing under the Bayonne Bridge. The U.S. Army Corps of Engineers estimated that raising the Bayonne Bridge would produce a \$3.3 billion national benefit, and that the ports indirectly create approximately 270,000 jobs and generate \$11 billion in annual national wages. The Bayonne Bridge Navigational Clearance Program will allow the largest post-Panamax ships, carrying more than 12,000 container units each, to pass under the bridge, increasing the overall capacity for the ports. Prior to the project, the largest ships allowed to pass under the Bayonne Bridge could carry only half that amount.

profile

BAYONNE BRIDGE / STATEN ISLAND, NEW YORK, AND BAYONNE, NEW JERSEY

BRIDGE DESIGN: HDR-WSP, a joint venture, New York, N.Y.

PRIME CONTRACTOR: Skanska-Koch Kiewit (SKK), a joint venture, Carteret, N.J., and Woodcliff Lakes, N.J.

PRECASTER: Bayshore Concrete Products, Cape Charles, Va.—a PCI-certified producer

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

OTHER CONSULTANTS: Arora and Associates P.C., Lawrenceville, N.J.; HNTB Corporation, Parsippany, N.J.; IH Engineers P.C., Princeton, N.J.; KPFF, Chicago, Ill.; and Thornton Tomasetti, New York, N.Y.

Feasibility Study

A feasibility study was performed in 2008 to determine the most effective way to increase the air draft of the Bayonne Bridge to 215 ft. As part of the feasibility study, many alternatives were investigated, including raising the roadway within the arch, building a new bridge, creating a new tunnel below the channel, jacking the arch up, modifying the existing bridge to a lift bridge at midspan, and instituting non-bridge alternatives such as ferry services or lock and dam.

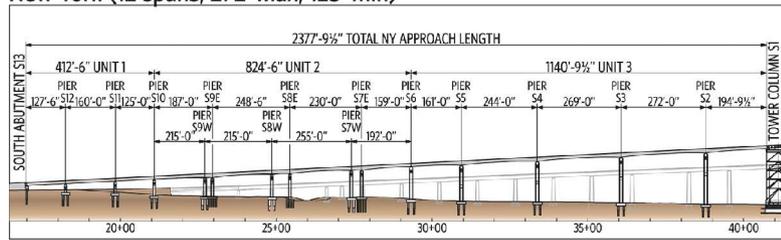
The study concluded that raising the roadway within the bridge's existing steel truss-arch span would be the most expedient and efficient method to achieve the increased navigational clearance while maintaining traffic on the bridge. Raising the roadway did not require any permanent right-of-way acquisition as the project remained within the existing bridge and approach right-of-way footprint. This limited the environmental and neighborhood impacts and made possible an environmental assessment in lieu of an environmental impact statement.

To achieve this goal, it was necessary that the steel trusses in the arch be strengthened, new arch portals be opened for the higher roadway in the arch span, and the existing arch portals be closed. Taller arch-transition towers were also needed to allow for the connection of the elevated roadway to the new arch portals.

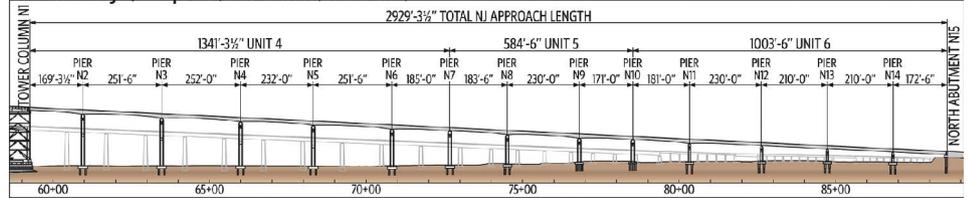
With the higher roadway elevation, the existing approach structures in New York and New Jersey required increased elevations and steeper grades to connect with the new arch span.

Project criteria required that the roadway be widened to provide roadway widths and shoulders to meet current American Association of State Highway and Transportation Officials (AASHTO) standards, provide a shared-use path for

New York (12 spans, 272' max, 125' min)



New Jersey (14 spans, 252' max, 171' min)



Pier layouts for the New York and New Jersey approach structures.

pedestrians/bicyclists, and accommodate potential future light-rail transit. Adding to the complexity of the project, contract criteria required that one lane of vehicular traffic in both the northbound and southbound directions be maintained during peak travel times throughout the project duration, thus requiring staged construction. Furthermore, construction zones for the approach structures were extremely tight, with private residences located within 30 ft of the bridge footprint. All these requirements were accommodated in the design and construction phases.

The New Bayonne Bridge

With an arch span of about 1652 ft from pin-to-pin, the Bayonne Bridge was the longest arch bridge in the world when it was completed in 1931, and remained so for 46 years. The project limits of the approach ultimately determined the steeper grades of the new approach roadways. The New York approach was constrained by the Walker Street overpass, large retaining walls, a school, a church, and a cemetery, while the New Jersey approach was constrained by the existing multilane JFK Boulevard underpass and existing entrance and exit ramps. These vertical clearance constraints resulted in 5.00% and 4.85% approach grades in New York and New Jersey, respectively. The existing approach grades were 4%.

The new approach structures have 24 piers and 52 spans with approach lengths of approximately 2377 and 2929 ft in New York and New Jersey, respectively. The new layout reduced the number of piers by 14, thereby opening up the visual sight lines to residents and pedestrians.

The Design Development Report addressed the use of precast concrete segmental construction and steel-plate girder construction for the approaches. PANYNJ chose the precast concrete alternative based on reduced cost, improved aesthetics, improved durability, and reduced maintenance cost. From an environmental assessment perspective, precast concrete was favored due to reduced traffic noise in the final structure and the elimination of over 1000 concrete truck trips through neighborhoods to place a concrete deck slab for the steel alternative. Overhead gantry erection eliminated the need for cranes (noise, air quality, local traffic disruption), except for erection of the precast concrete pier tables.



Location of the Bayonne Bridge over the Kill Van Kull.

PORT AUTHORITY OF NEW YORK AND NEW JERSEY, OWNER

BRIDGE DESCRIPTION: Twin precast, post-tensioned segmental concrete box girders with a total single box length of 10,614 ft; precast segmental concrete columns and pier caps

OTHER MATERIAL SUPPLIERS: Self-launching gantries: Handan China Railway Bridge Machinery Co LTD, Handan City, China; Precast segment form systems: Ninive, Casseforme, Italy; Onsite segmental forms: Doka USA, Little Ferry, N.J.; Bearings and finger joints/modular deck joints: Mageba USA, New York, N.Y.; Segmental epoxy: Pilgrim Permocoat Inc., Tampa, Fla.; Segmental grout: Sika U.S.A., Lyndhurst, N.J.; Stainless-steel reinforcement in precast: CMC, Cincinnati, Ohio; Stainless-steel reinforcement in cast-in-place concrete: Salit Specialty Rebar, Niagara Falls, N.Y.; Post-tensioning grout: Five Star Products Inc., Shelton, Conn.

STRUCTURAL COMPONENTS: 512 precast concrete substructure segments, 1079 precast concrete superstructure segments, 5179 ft of 60-in.-diameter drilled shafts, 12,484 yd³ of cast-in-place concrete footings

BRIDGE CONSTRUCTION COST: \$744 million (low-bid cost); \$1430/ft² (total project)



Balanced-cantilever construction for the Bayonne Bridge approaches.

The structure is designed for an additional 100 years of service life after the opening of the reconstructed facility. All reinforcement in the deck or anchored in the deck is stainless steel.

Precast concrete segmental construction is effectively being used for the balanced-cantilever superstructure as well as for the substructure piers and pier caps. Hollow precast concrete segments were used at all 24 of the two-column pier locations, as well as the post-tensioned precast concrete pier-cap segments. Precast concrete segmental construction was used for all 52 spans of the New York and New Jersey approach superstructures. All designs were in accordance with the *AASHTO LRFD Bridge Design Specifications*, 6th edition.

Approach Design and Construction

The design of the hollow precast concrete columns and arched precast concrete pier caps included aesthetics and architectural face treatments to complement the existing architecture of the original 1931 Bayonne Bridge approach piers. Where

the substructures support the typical 36-ft-wide roadway, a combined Type 1 two-column pier is used. In the areas adjacent to the abutments on each end of the bridge, where the acceleration and deceleration lanes add an additional 12 ft to the roadway template, side-by-side Type 2 single-column piers are used (see the CBT article in this issue for more information on the piers).

The superstructure is being cast and erected as twin single-cell box girders with variable width to accommodate acceleration and deceleration lanes. The northbound roadway accommodates a 12-ft-wide shared-use path, while the southbound roadway is designed to accommodate future light-rail transit.

All precast concrete segments are being cast in Cape Charles, Va. Precast concrete elements are barged 300 miles on the ocean to Bayonne, N.J., where they are off-loaded and stored until needed for erection. Superstructure segments are either 10- or 14-ft-deep, and the maximum haul weight is 112 tons.

Key Design Parameters and Principal Quantities	
Superstructure concrete strength	10 ksi
Substructure concrete strength	8.5 ksi
Superstructure concrete volume	44,900 yd ³
Substructure concrete volume	15,600 yd ³
Superstructure theoretical (average) thickness	2.33 ft
Superstructure reinforcing bar density ²	192 lb/yd ³
Superstructure post-tensioning (longitudinal)	5.1 lb/ft ²
Superstructure post-tensioning (transverse)	1.0 lb/ft ²
Substructure reinforcing bar density	160 lb/yd ³
Substructure post-tensioning steel density	70 lb/yd ³

¹ Theoretical average thickness is the volume of superstructure concrete divided by the total deck area. It is a helpful parameter for conceptual estimation of concrete quantities as it varies with the average span length for a given project.

² Approximately 70% of the reinforcement was stainless steel, and the remaining 30% was epoxy coated.

Balanced-cantilever construction of the superstructure is performed with the use of overhead self-launching gantries. Superstructure erection is performed at night with the existing bridge closed to traffic, while the permanent post-tensioning is installed and stressed during daytime hours.

Construction Status

On February 20, 2017, two lanes of northbound traffic were transferred onto the new upper roadway. Demolition of the existing suspended-arch floor system has commenced, with June as the target removal completion date. Larger container vessels will then be able to access the port facilities. Removal of the existing approach structure is now under way.

The first task for the southbound approach is the installation of the drilled shafts, followed by construction of the footings. Fabrication of the precast concrete segments for the southbound substructure is essentially complete and casting of the superstructure elements was approximately 65% complete as of April. It is anticipated that construction of the southbound structure will be completed in 2019. 

Joseph LoBuono is vice president and major bridge technical director with HDR in Newark, N.J., and Chester Werts is a senior bridge engineer with HDR in Olympia, Wash.

EDITOR'S NOTE

Another article about the Bayonne Bridge project is included in this issue on page 28.

AESTHETICS COMMENTARY

by Frederick Gottemoeller



Talk about a challenge: significantly altering one of the iconic bridges of the twentieth century, designed by one of the century's master builders, Othmar Amman, and doing that while the bridge is in continuous use! I don't know how the design team slept at night. But they certainly rose to the challenge.

Let's start with the decision to use precast concrete segmental construction for the approach spans. It significantly changes the look of the bridge in comparison to the steel-plate girder spans of the original, but the longer spans and fewer

piers open up views through the structure that didn't exist before, and create opportunities for new ground-level activities that will benefit all of those people who live or work near the bridge. Plus, the more massive concrete superstructure absorbs road noise, an underappreciated benefit of concrete segmental construction that will improve the local environment aesthetically as well as physically.

Then there are the new approach piers. The taller and wider piers are more prominent elements in the scene than were the original piers, but visual continuity with the original piers is established by borrowing their arched pier caps and the horizontal grooves of their columns.

I. M. Pei, the architect who redesigned the Louvre, stated the challenge of altering famous structures this way: "How do we make history live, and still point the way to the future?" The designers of the Bayonne Bridge reconstruction have shown how.

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THERE IS NO EQUIVALENT



Photo courtesy of USC/Gus Ruelas.



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PCI certification offers a complete regimen covering personnel, plant, and field operations. This assures owners, specifiers, and designers that precast concrete products are manufactured and installed by companies who subscribe to nationally accepted standards and are audited to ensure compliance.

To learn more about PCI Certification, please visit

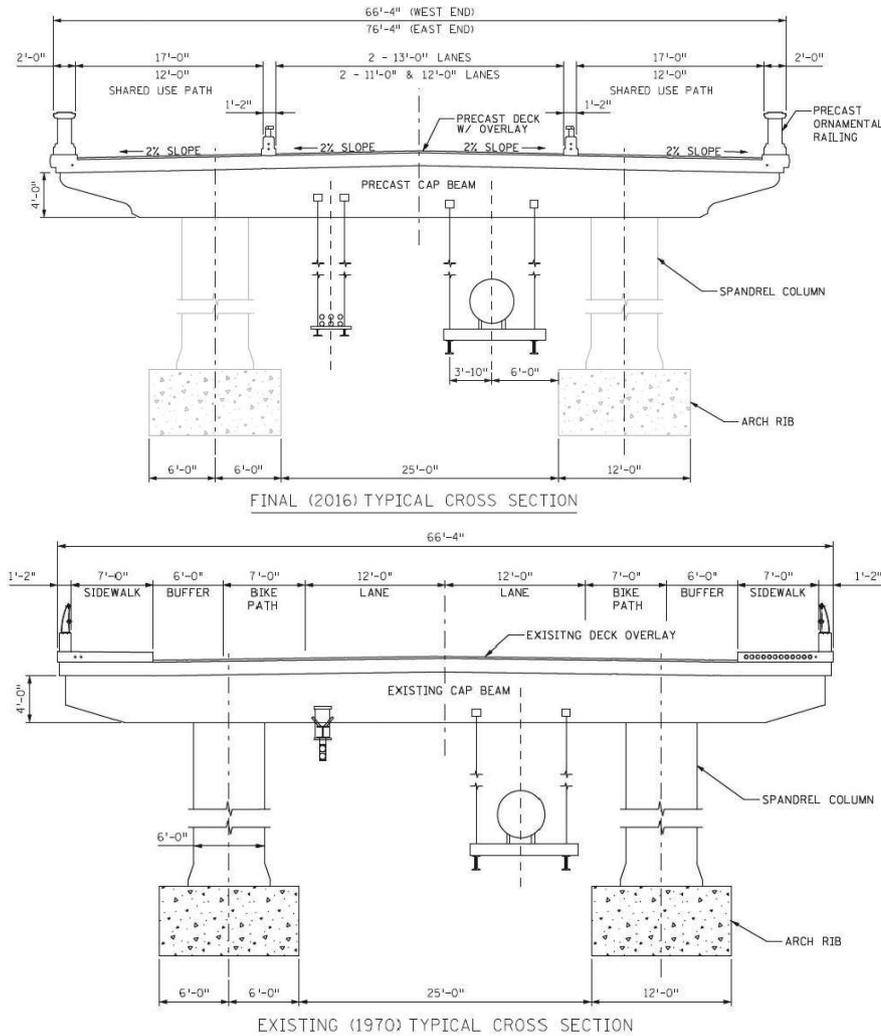
www.pci.org/certification



FRANKLIN AVENUE BRIDGE

ANALYSIS, DESIGN, AND ACCELERATED BRIDGE CONSTRUCTION

by Dan Enser, HNTB Corporation; Arne Johnson and Dr. John Lawler, Wiss, Janney, Elstner Associates Inc.; and Paul Backer, Hennepin County



New (2016) typical cross section (top) and existing (1970) typical cross section (bottom). All Figures and Photos: HNTB Corporation.

The historic Franklin Avenue Bridge in Minneapolis, Minn., was built in 1923 and rehabilitated in 1970. The 1050-ft-long, five-span, open-spandrel concrete deck arch structure has served as a vital link over the Mississippi River for nearly 100 years, connecting Minneapolis and St. Paul neighborhoods. Degradation and changing usage led to the full replacement of the deck and spandrel cap beams during the summer of 2016. By coupling accelerated bridge construction (ABC) techniques with prefabricated bridge elements and systems (PBES), the replacement of the superstructure was completed during a 116-day closure.

Inspection of the existing bridge revealed many elements were deteriorated and laden with chlorides. The original pier, arch rib, and abutment deterioration consisted of spalls, delaminations, and longitudinal reflective cracks along the top and bottom of the arch ribs in line with the Melan truss elements. The majority of the deterioration was caused by chloride intrusion and freeze-thaw damage. In addition, the as-inspected operating rating of the arch ribs of span 1 and span 5 was 0.63 (below 1.0); therefore, the bridge was load-posted to 18 tons

profile

FRANKLIN AVENUE BRIDGE / MINNEAPOLIS, MINNESOTA

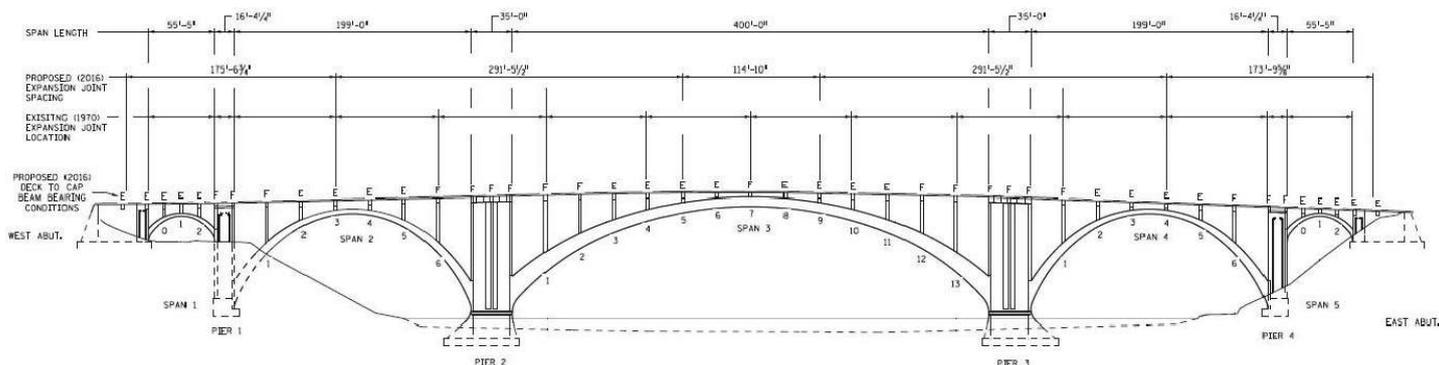
BRIDGE DESIGN ENGINEER FOR REHABILITATION: HNTB Corporation, Golden Valley, Minn.

SPECIALITY CONSULTANT: Wiss, Janney, Elstner Associates Inc., Northbrook, Ill.

PRIME CONTRACTOR: Kraemer North America, Burnsville, Minn.

PRECASTERS: Precast concrete deck panels: Kraemer North America, Burnsville, Minn.; precast concrete cap beams: Forterra Building Products, Elk River, Minn.—a PCI-certified producer; precast concrete ornamental railing panels: American Artstone, New Ulm, Minn.

OTHER MATERIAL SUPPLIERS: Stainless steel plates: Ryerson, Minneapolis, Minn.; PTFE sheets: D.S. Brown Company, North Baltimore, Ohio; expansion joints: Commercial Fabricators, Bridge View, Ill.; DUCTAL concrete (UHPC): Lafarge North America, Chicago, Ill.; premixed polyester polymer concrete (PPC): KWIK BOND, Benicia, Calif.



Bridge span layout with existing and proposed joint locations and deck-to-cap beam bearing conditions (E = expansion; F = fixed).

(two-axle, single-unit), 32 tons (three-axle, tractor-trailer), and 32 tons (four-axle, tandem). Extensive degradation of major bridge elements, together with low load postings, warranted full replacement of the deck and spandrel cap beams.

Closing the bridge for an extended period would have created major hardship to the traveling public. After consideration of the structural system and user impacts, the owner, Hennepin County, elected to use ABC methods and PBES to accomplish a short period of full closure in the summer, when activities at the nearby University of Minnesota and Augsburg College were reduced. The local community supported this full closure as opposed to the prolonged construction period associated with cast-in-place construction.

With the decision to close the bridge for four months to accelerate construction, PBES became the logical solution. Precast concrete spandrel cap beams, deck panels, and ornamental railing were chosen as the PBES.

Improvements to the Structure

Reduction in the number of expansion joints was critical to extend the life of the structure. The greatest levels of degradation were found at the 15

existing expansion joints, which had allowed chloride-laden water direct access to the underlying, non-air-entrained original concrete elements. Reducing the number of expansion joints required a radical revision of the structural connectivity between the deck and cap beams. By allowing the deck to translate over the spandrel columns, the thermal forces within the spandrel columns and arch rib were greatly reduced. Releasing the connection between the deck and cap beams required a reliable, low-friction bearing assembly that would accommodate the translation associated with thermal movements.

A sliding-plate joint was developed, consisting of a polished stainless-steel plate embedded in the underside of the deck panels that slid on polytetrafluoroethylene (PTFE) bearing sheets recessed into stainless steel plates on top of the precast concrete cap beams. This innovative detail supported the deck loads and allowed the precast concrete deck panels to slide over the cap beams, offering minimal resistance to longitudinal translation.

Detailed structural models were developed to evaluate the outcome of the proposed approach and to predict the built-up forces within the system in both restrained and released configurations. Results from this parametric comparison

strongly supported releasing the deck from the cap beams. While 15 of the existing expansion joints were removed, six were installed away from the substructure elements, reducing deterioration potential and extending bridge service life.

Restoring the original 1923 spandrel columns in spans 1 and 5, which had been removed during the 1970 rehabilitation, addressed the unbalanced flexural demand on the arch ribs by establishing a more uniform loading on the arch ribs. The effort resulted in increasing the operating load rating factor from 0.63 to 3.62.

In addition, the following improvements were made to the structure:

- The bridge cross section was revised to accommodate a multimodal facility.
- Spandrel cap beams with historic scroll ends were used.
- Full-depth precast concrete deck panels were joined with ultra-high-performance concrete (UHPC).
- A premixed polyester polymer concrete (PPC) overlay was installed to protect the deck panels and construction joints from water ingress.
- Ornamental railing panels replicated the original 1923 design.

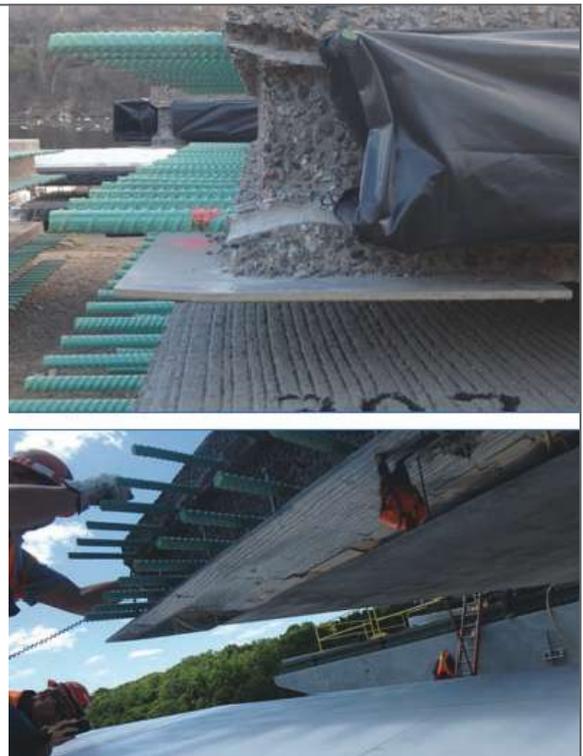
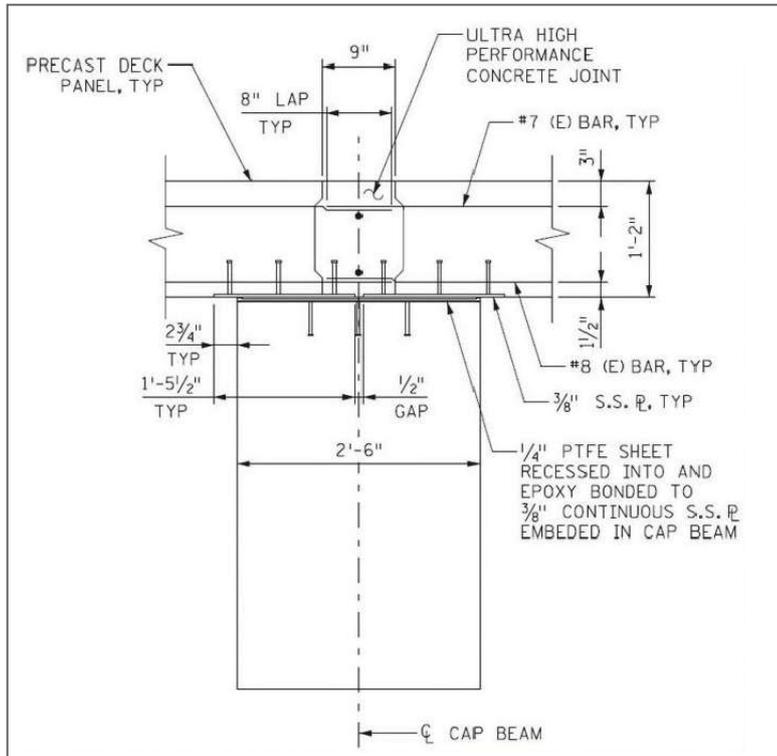
HENNEPIN COUNTY, OWNER

BRIDGE DESCRIPTION: Historic 1050-ft-long, five-span, open-spandrel concrete deck arch bridge built in 1923 over the Mississippi River; each arch rib contains a Melan lattice truss.

STRUCTURAL COMPONENTS: Three-hundred-fifty 14-in.-thick full-depth precast concrete deck panels; 33 precast concrete spandrel cap beams; 10 precast concrete pier cap beams; 163 precast concrete ornamental railing panels; 167 cast-in-place concrete pilasters; 350 yd³ ultra-high-performance concrete; 2200 ft concrete parapet, 66,500 ft² polyester polymer concrete

BRIDGE CONSTRUCTION COST: Bid: \$43,097,946.99 (\$590/ft²)

AWARDS: ACEC National Honor Award; ACEC Local Grand Award; APWA Local and National Project of the Year; 2016 MnDOT AGC MN Bridge Construction Award; 2017 MN Environmental Stewardship Award by MnDOT



Typical sliding-plate joint and precast concrete deck panel joint.

Precast Concrete Elements

Deck Panels

Three types of full-depth precast concrete deck panels were designed: expansion, sliding, and fixed. The panel length matched the spacing between spandrels, with the maximum length being 27 ft 11½ in. The panel width was 8 ft 9 in., to permit off-site casting and delivery to the bridge site.

The contractor fabricated the 350 reinforced concrete deck panels at a casting yard located approximately one mile upstream of the bridge. The proximity of the bridge allowed for barging the deck panels, thus mitigating logistical transportation problems and risks during the closure period. The yard was approximately 4.5 acres and consisted of five custom-made casting beds in conjunction with a custom-built steam-cure system that allowed the general contractor to fabricate up to 30 precast concrete deck panels per week. Rigorous quality control and assurance measures ensured that each unique deck panel would fit into its respective location.

Spandrel Cap Beams

The cap beams were designed as reinforced concrete elements. The spandrel cap beams were fabricated at a

Fortera building products manufacturing facility in Elk River, Minn., and the cap beams over piers were fabricated by the contractor. To facilitate the ABC approach, embeds to support temporary works and cap beam connectivity to spandrel columns were incorporated into the design. Cap beams at sliding and expansion joints had stainless-steel plates embedded in the top of the cap beam, with a recess of 1/8 in. for the PTFE sheets.

Connecting the new cap beams expediently to the existing spandrel columns was critical. Developing a fully integral connection was not feasible, so a quasi-fixed connection was established by drilling and using epoxy adhesive to install reinforcing bars in the existing spandrel columns. A drill depth of 3 ft 6 in. was specified to provide adequate development of the new reinforcement in the existing concrete. For the other end of the connection, 2-in.-diameter corrugated plastic (HDPE) ducts, typically used for post-tensioning, were placed in the precast concrete cap beams during fabrication.

Ornamental Railing Panels

Precast concrete ornamental railing panels were designed and fabricated to replicate the original 1923 design. The panels were connected to steel posts that were then connected to

the deck. Each post was located at an ornate pilaster. Once the railing panels were installed, concrete was placed in the hand-formed pilaster, encapsulating the post and the end of each precast concrete railing panel.

Use of Innovative Materials

Innovative materials made the Franklin Avenue Bridge project feasible. UHPC allowed the deck to be continuous over the supporting cap beams with narrow joints between deck panels. The new cap beams, at 2 ft 6 in. wide, would not have accommodated traditional reinforcement bar splices without significant additional falsework. The rapid strength gain of UHPC allowed the contractor to move swiftly to the next erection step. The physical properties of UHPC, together with its material characteristics, provided a perfect application for this material. It is the first project in Minnesota to use UHPC to join deck panels and the second largest application of UHPC in the United States.

The PPC overlay provided a durable roadway surface with minimal dead load, allowed construction equipment on the bridge four hours after placement, and provided a waterproofing system to protect the deck panel joints.

ABC

The bridge was closed on May 8, 2016, and on-site construction began. The use of ABC together with PBES allowed for an accelerated construction time frame and minimized disruption to the public. On September 1, 2016, after 116 days, the third rehabilitation of the iconic Franklin Avenue Bridge was complete and the bridge was opened to traffic, to the great appreciation of the public.

Lessons Learned

Pre-ABC planning is paramount to a project's success and includes bringing all contractual parties together to work out, in fine detail, how each operation will take place. It is necessary to eliminate as many potential issues as possible and have contingency plans in place in case an operation does not proceed as planned.

When using PBES on an existing structure, a recent survey of the existing bridge elements is critical to develop accurate shop drawings and ensure proper fit-up of the precast concrete elements.

Clearly communicated fabrication and erection tolerances for all precast concrete elements are also necessary. Planning efforts need to address quality assurance procedures for both the contractor and the inspectors. Topics that should be discussed include: what will be measured, when will it be



Accelerated bridge construction (ABC) operation.

measured, how will it be measured, and what needs to happen if a measurement is not within tolerance.

For concrete arch bridges, erection plans need to take thermal movements into account, in addition to dead load deflections. Arch ribs deflect very little under changes in dead load, but deflect considerably from thermal changes; this

must be considered when determining the setting elevations of precast concrete elements.

The long-term durability of the precast concrete deck panel system relies on the UHPC joint performance. Deck panel edges must have a roughened surface with aggregate exposed. Joints must have a saturated-surface-dry condition immediately prior to UHPC placement. UHPC requires proper forming, mixing, placement, and curing. Strength gain in UHPC is temperature-sensitive and the placement sequence must be well thought out to avoid loading joints prematurely. ⚠

Dan Enser is a project manager with HNTB Corporation in Golden Valley, Minn. Arne Johnson and Dr. John Lawler are principal and associate principal, respectively, at Wiss, Janney, Elstner Associates Inc. in Northbrook, Ill. Paul Backer is a senior construction engineer with the Hennepin County Transportation Department in Medina, Minn.

Key ABC tasks and timeline:

ABC task	Task completion (days after closure)
Existing deck removal	Day 36
Existing cap beam removal	Day 39
Precast concrete cap beam erection	Day 43
Precast concrete deck panel erection	Day 51
UHPC placement at deck panel joints	Day 79
Ornamental steel railing post placement (north sidewalk)	Day 101
Precast concrete ornamental rail panel installation and pilaster casting (north sidewalk)	Day 113
PPC overlay placement	Day 114
Bridge opened to traffic	Day 116

Bayonne Bridge—Design and Construction Features

by Joseph LoBuono and Chester Werts, HDR



Traffic relocated to the new upper level of the Bayonne Bridge using the northbound approach structure. All Photos and Figures: HDR.

On February 20, 2017, one lane of traffic in each direction was relocated to the new upper level of the Bayonne Bridge. With the traffic relocated to what will become the northbound structures, demolition of the existing arch floor commenced. The Port Authority of New York & New Jersey planned the construction of the Bayonne Bridge Navigational Clearance Program to coincide with the expansion of the Panama Canal, so that the new generation of larger container vessels had sufficient clearance to pass under the bridge and access the Ports of Elizabeth and Newark. Accordingly, every effort was made to expedite the elimination of the existing arch floor of the Bayonne Bridge, thus increasing the air draft from 151 to 215 ft.

For this to occur, both the arch structure and the northbound approach structures had to be ready to transfer traffic onto the elevated roadway. This article highlights some of the design features used to expedite the construction schedule. These include using combined precast concrete pier caps, a pipe strut to brace the taller Type 1 piers

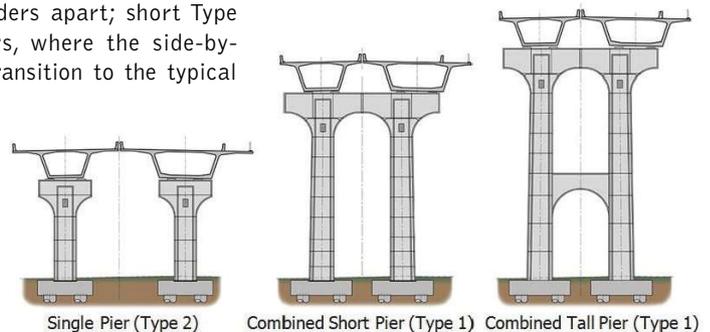
during construction, split superstructure pier segments, and balanced-cantilever construction at expansion joints.

Approach Substructure

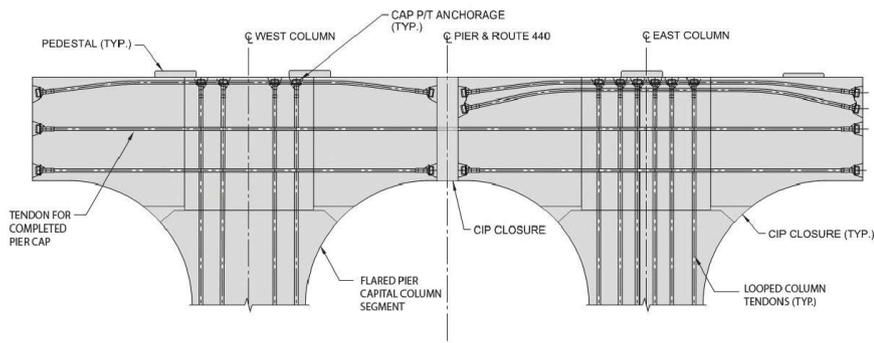
The geometry of the precast concrete columns and pier caps was created to complement the original architecture of the 1931 Bayonne Bridge piers, while providing an efficient structural section that could be cast, transported, and erected as expeditiously as possible. Approach-structure piers can be divided into three groups: Type 2 single piers used closer to the abutments, where the wider roadways shift the box-girders apart; short Type 1 combined piers, where the side-by-side structures transition to the typical

roadway width; and tall Type 1 combined piers, where intermediate haunched cross beams connect the tall, slender columns at approximately midheight.

Type 1 combined precast concrete pier caps were effectively used to accelerate the construction of the substructure in advance of the segmental superstructure construction. The three-piece precast concrete pier caps are supported by the flared-pier capital segment that forms the base of the pier cap arch when complete. Precast concrete pier segments are constructed similarly to the precast concrete segmental columns, with both vertical and horizontal post-tensioning (PT) bars temporarily clamping the segments together and providing the required compression on the epoxy adhesive joints until the final multi-strand tendons are stressed. Transverse horizontal multi-strand tendons provide capacity for the cantilevered pier cap segments, and looped column multi-strand tendons are stressed at the top of the pier cap. Precast concrete segmental construction of the pier caps expedited the construction schedule and was exceptionally conducive to the staged construction of the northbound and southbound roadways. Each pier cap could be quickly constructed independently of the adjacent cap. When the two side-by-side structures are completed, the cast-in-place reinforced concrete closure will be placed and the two pier caps will then be post-tensioned together forming a framed two-column pier.



Precast concrete pier types.



ELEVATION VIEW

Combined pier post-tensioning for the Bayonne Bridge Type 1 piers.

For the Type 2 single piers, the centerline of the box girder is concentric to the centerline of the column on both the northbound (east) and southbound (west) structures. But the Type 1 combined piers are laid out such that the centerline of northbound structure's box girder is eccentric to the associated Type 1 column section. This 7.7-ft eccentricity is due to the additional width of the northbound structure, which accommodates a 12-ft-wide shared-use path and an additional pedestrian barrier. There is also the constraint on the column location due to the existing structure's exterior girder.

To accelerate delivery of the Bayonne Bridge project, the decision was made to maintain all construction within the existing right-of-way and obtain underground easements where footings went outside the right-of-way lines. With this strategy, the new facility did not require the acquisition of property, so environmental documents were prepared and approved as an environmental assessment rather than an environmental impact statement. This saved a minimum of three years in the design process.

The single most important schedule enhancement was the redesign of the as-bid

construction sequence that required the partial construction of the southbound substructure to brace the northbound column. The as-bid contract drawings also included a construction sequence for the tall Type 1 piers that used cast-in-place construction for both the southbound and northbound columns up to the top elevation of the intermediate cast-in-place concrete cross beam beneath the existing structure, which remained in place during northbound construction. This intermediate cross beam provided stability to the northbound piers and reduced the overall lateral movements in the columns during construction, and would continue to do so throughout the life of the structure.

After the construction contract was awarded, an effort was made to develop a modified construction sequence that would expedite the construction schedule for the substructure and therefore for all the approach structures. One modification was constructing both the northbound and southbound piers to be fully independent precast concrete structures. Another modification was using temporary steel pipe struts under the east hammerhead cantilevers of the northbound pier caps



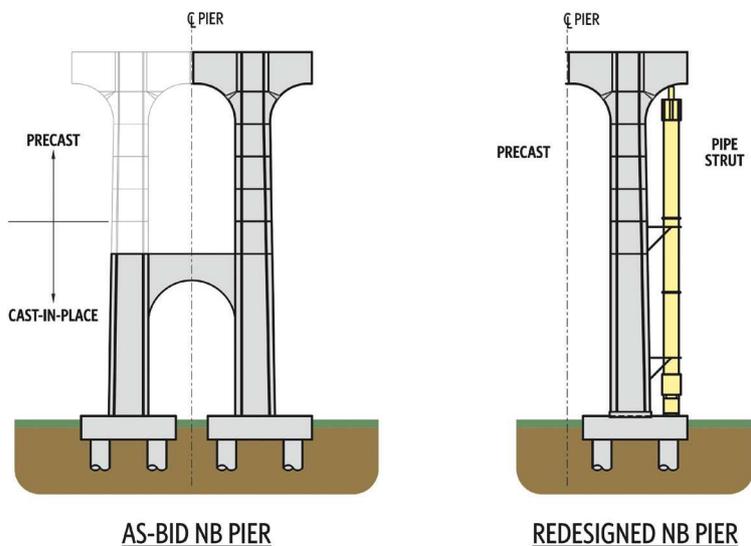
Erection of precast concrete column segment. Column location constrained by existing edge girder.

to mitigate transverse overturning moments and transverse deflections during construction. The pipe strut concept eliminated the need to build the southbound piers and cross beams to brace the northbound columns.

There were many design and construction challenges that accompanied this bold move to temporarily support the eccentric northbound superstructure with struts. Design challenges included the redesign of the tall single columns, the design of the steel pipe strut connections at the underside of the pier cap, and the design of a new steel space truss with precast concrete cladding to replace the cast-in-place concrete cross beam. Challenges during construction included properly engaging the pipe strut load path and predicting and monitoring both the forces in the struts and deflections of the piers. The change to a fully precast concrete pier, as well as the additional change of the cast-in-place crossbeam to a steel space truss, accelerated construction by using all prefabricated components.



Temporary pipe strut bracing a northbound Type 1 pier.



As-bid and redesigned Type I pier during construction of northbound superstructure.



Rendering of twin side-by-side precast concrete box girders and completed pier. The northbound segment is wider to accommodate a 12-ft-wide shared-use path and an additional pedestrian barrier.

Approach Superstructure

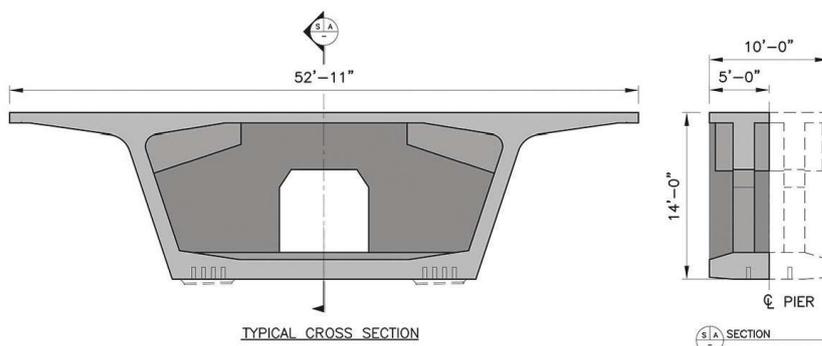
A total of 1079 precast concrete box-girder segments are being erected using a balanced-cantilever method to construct more than two miles of segmental approach roadway. The precast concrete segments for the twin structures range in width from 39 ft 3 in. for the typical southbound segment to 64 ft 10 in. at northbound abutment N15, with segments weighing up to nearly 112 tons. Constant-depth girders having spans of up to 210 ft and haunched girders with spans of up to 272 ft are used for the approach structures.

Split-pier segments are used on the balanced-cantilever pier tables at the haunched piers to maintain the exclusive use of precast concrete construction at the piers and to expedite the construction erection schedule. Haunched girders are 14 ft deep at the pier, and with the weight of the diaphragms it was not possible to keep the total weight of the segment below 112 tons. The weight limit was controlled by the maximum load of the transported segment and trailer that could cross the existing arch and the overall length of the trailer that would have to navigate the residential neighborhoods adjacent to the bridge. Cast-in-place diaphragms were also considered during the design phase; however, the precast concrete split-pier segment was chosen because it would allow faster erection and eliminate the potential for construction delays caused by the placement of diaphragm reinforcement or concrete. The diaphragm was then effectively split in half, with two parallel walls providing the load path to the bearings.

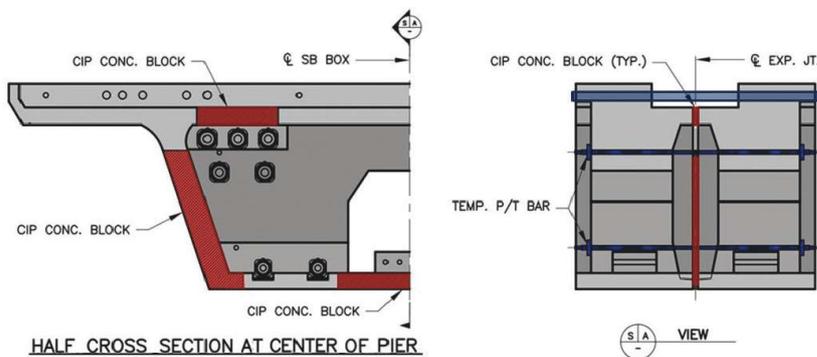
Balanced-cantilever construction was consistently used at all pier locations, including the expansion-joint piers, which further expedited the construction schedule and eliminated the need for end-span falsework at high-level expansion joints. Approach structures ranging in length from 2377 to 2929 ft required multiple



Gantry erection of cantilever at expansion pier and split-pier segment erection by crane.



Precast concrete split-pier segments for balanced-cantilever pier tables at haunched piers.



Precast concrete expansion-joint segment details (as-bid concept).

expansion joints to accommodate both the long-term concrete movements and the cyclic thermal and service movements of the structure. The design team located the expansion joints at the piers and adopted a construction sequence that would accommodate a similar balanced-cantilever construction sequence as the typical cantilevers. To do this, the expansion-joint segments were spaced a few inches apart and temporary cast-in-place concrete blocks were cast between the segments, which were then post-tensioned together using temporary PT bars.

Once the two expansion segments were post-tensioned together, the construction sequence was similar to the split-pier segments, with the adjacent up-station and down-station segments forming the four-segment pier table, and an additional three to four segments erected in cantilever on either side. After the next two spans were completed, the contractor could then go back, release

the bearing restraints, remove the temporary PT bars, and cut the temporary cantilever multistrand tendons one at a time, thereby releasing the adjacent expansion segments.

Conclusion

Maximizing the use of precast concrete and prefabricated design features, as well as eliminating the need to build a portion of the southbound substructure under the existing structure using cast-in-place concrete, streamlined the construction sequence and reduced the overall construction schedule. 

Joseph LoBuono is vice president and major bridge technical director with HDR in Newark, N.J., and Chester Werts is a senior bridge engineer with HDR in Olympia, Wash.

EDITOR'S NOTE

Another article about the Bayonne Bridge project is included in this issue on page 20.

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Broad-based ABC Policy: WSDOT's Bridge Design Manual

by Patrick Gallagher, Alpha & Omega Group (formerly with Washington State Department of Transportation)

Accelerated bridge construction (ABC) has been a part of the Washington State Department of Transportation's (WSDOT's) bridge design philosophy before the term was popularized in recent years. Washington state has a long history of pushing the envelope and trying new and innovative bridge designs. With the recent attention given to ABC, WSDOT decided to embrace this new movement and formalize their position on the topic.

The WSDOT *Bridge Design Manual*¹ (BDM) is unique. Like many states, WSDOT's BDM provides standard construction drawings. But it also puts an emphasis on standardizing design techniques. Being in a part of the country where bridge designs are typically dominated by seismic analysis, it can be difficult to create broad-range construction standards. So, the BDM often relies upon standardizing how a bridge ought to

be designed and how other codes^{2,3} are applied. It also offers suggestions to the designer regarding the fabrication and constructability of bridges and structures.

The BDM covers a wide array of topics regarding ABC. But the focus of this article will be project delivery methods and the precast concrete bent system.

How We Got Here

Washington state has vast natural beauty and is also one of the faster growing places in the country. With a desire to add transportation capacity and protect the unique beauty of the state, precast concrete bents diminish the seemingly offensive activity of road construction. Whether it be minimizing traffic disruption, minimizing workers' exposures to hazards, or optimizing time for fish migration, erecting bridge piers and cap beams quickly is in everyone's best interest.

Like design-build (DB), what makes a project an attractive candidate for ABC is reduced construction time. DB offers time savings by overlapping design and construction efforts, and by encouraging collaboration. ABC speeds up the construction time by overlapping linear-flowing construction activities. This can be accomplished by prefabricating bridge components off-site while other activities are taking place on-site, allowing construction tasks that used to be done one after the other to be done at the same time.

The construction manager/general contractor project delivery method capitalizes on a specific contractor's skills. While it may not provide delivery as rapidly as DB, it too complements ABC. Prefabricating bridge components to a specific contractor's interests and abilities offers a boost of speed because the details are optimized for that contractor's expertise.

When to Use ABC

Decisions affecting the choice to use ABC are often made by a traffic engineer or a project manager early in a project's development. These individuals are often interested in concepts and project schedules, not structural details. By the time a bridge is being designed, the opportunity for a bridge design engineer to apply ABC has often passed.

ABC ought to be presented to decision makers early in the project's development. To aid a WSDOT region engineer in deciding whether or not to apply ABC, the WSDOT BDM offers a design impact questionnaire and an ABC decision flow chart. These tools were borrowed from the California Department of Transportation. The questionnaire uses a weighted scoring system based on the relevance and priority of concerns



Erection of precast concrete crossbeam at Nalley Valley Interchange, Tacoma, Wash.. Photo: Geoff Swett, Washington State Department of Transportation.

on the overall project. With that score, the region engineer enters the flow chart and, based on the responses to ABC-related questions, leaves the flow chart with a recommendation to apply an ABC approach or not. The scoring system gives a way to measure how strongly ABC should be considered, and the broad questions in the flow chart give the region engineer some room for judgment. The expectation is that ABC will be encouraged throughout this process, with an objective consideration for projects that are clearly best delivered by conventional means.

Benefits of Prefabrication

Space on a jobsite is precious. With more space taken up by construction activities, less space is available for traffic, or more disruption is done to the environment. Simply shifting activities off the jobsite adds tremendous value to a project. Precast concrete bents take major, critical construction activities and remove them from the jobsite. Space will still need to be allocated for shaft and footing construction. But once that work is complete, space can be used to put traffic back onto the highway, or simply to get out of the way and let nature continue to flourish.

Prefabricating bridge components is not a new idea. Precast, prestressed concrete girders have been around for decades. But the idea of prefabricating a substructure in a high seismic zone offers a tremendous challenge. The American Association of State Highway and Transportation Officials, *Guide Specifications for LRFD Seismic Bridge Design*³ requires that damage from a seismic event will not occur at connections. Traditionally, connection strength in prefabricated members is the weak point, and developing a connection stronger than the connected members is a challenge. The WSDOT BDM provides structural details and a design methodology for precast concrete bents to ensure this criterion is met.

Through the efforts of university research,⁴ a grouted-duct system has been developed to construct moment-resisting connections. By casting voids in one member using a corrugated steel duct, reinforcing bars extending from an adjacent member can be inserted into the voids. After the void is grouted, the full capacity of the reinforcing bars can be developed. Another moment-



Erection of precast concrete pier cap on precast columns, Interstate 5/US 12 interchange at Grand Mound, Wash. Photo: Patrick Gallagher, Alpha & Omega Group.

resisting and ABC friendly connection that is backed by large-scale experimental research⁴ is a unique socket connection between a precast concrete column and cast-in-place footing. Both of these connection systems offer straightforward methods to design a wide array of bridge configurations, resist the same loads as their cast-in-place counterparts, and can be tailored to an engineer's or contractor's preferred construction techniques. They can be applied to columns, footings, shafts, cap beams, and abutments. Similar methods have been applied to grout pockets in prefabricated concrete decks.

An Extraordinary Document

The WSDOT BDM is an extraordinary document, especially as it relates to ABC. It provides excellent guidance to project managers, bridge designers, and contractors. It offers a single-point resource for many aspects of ABC, including technology, construction techniques, and options for handling and shipping large components across the entirety of a project's development. In addition, it is a great design aid for the precast concrete bent system, which is an excellent achievement in and of itself.

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Patrick Gallagher is a structural project manager with Alpha & Omega Group in Raleigh, N.C., and formerly worked for the Washington State Department of Transportation.

EDITOR'S NOTE

Examples of projects where ABC concepts have been used, including a brief description of benefits and reasons for using ABC and lessons learned, are available on the WSDOT Bridge and Structures ABC Resources website.

The following FHWA publications present design examples for precast bents:

- *Precast Bent Systems for High Seismic Regions Appendix B, Publication Number FHWA-HIF-031-037-B.*
- *Precast Bent Systems for High Seismic Regions Appendix C, Publication Number FHWA-HIF-031-037-C.*



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Control of Concrete Cracking in Bridge Decks: Are We There Yet?

by Dr. Henry G. Russell, Henry G. Russell Inc.

According to a recent National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice, cracking in full-depth, cast-in-place concrete bridge decks continues to be a major concern for bridge owners, particularly in bridge decks exposed to severe environments.¹ Cracks provide a direct path for water and chlorides to penetrate the concrete and reach the reinforcement. This, in turn, can lead to corrosion of steel reinforcement and degradation of the concrete.

Bridge Deck Cracking

The NCHRP report¹ identified successful practices to reduce bridge deck cracking. These generally relate to reducing drying shrinkage of the concrete and reducing temperature differences. Drying shrinkage can be reduced by limiting the amounts of cementitious materials and water in the concrete and by using the largest practical size of aggregate in combination with appropriate construction practices. These practices include avoiding high-compressive-strength concrete, applying wet curing immediately after finishing the concrete surface, continuing wet curing for at least seven days, and applying a curing compound after the wet curing to slow moisture loss from the concrete.

Temperature differences can be controlled by limiting the temperature of the fresh concrete at the time of placement and ensuring that the concrete temperature does not increase too much as the concrete hydrates. Nighttime concrete placement can also be beneficial, particularly in hot climates. Overall, no single effective practice to reduce concrete cracking in bridge decks was identified by the NCHRP report.¹

Practices tried by some states to reduce shrinkage and shrinkage cracking



Application of wet curing immediately after finishing the concrete surface and continuing wet curing for at least seven days are successful practices to reduce bridge deck cracking. Photo: Michigan Department of Transportation.

include the use of supplementary cementitious materials, internal curing using prewetted lightweight aggregate, shrinkage-reducing admixtures, or shrinkage-compensating concrete.

The American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*² provides requirements for minimum amounts of reinforcement and maximum spacing of reinforcement to control crack widths. Nevertheless, bridge owners find the need to supplement the AASHTO LRFD specifications with their own requirements. The control of cracking in bridge decks for aesthetic, durability, and structural reasons becomes increasingly important as service-life goals are extended and higher-strength concrete, higher-strength reinforcement, and different types of reinforcement are used in bridge construction.

Other Bridge Components

In addition to full-depth, cast-in-place concrete bridge decks, the NCHRP report¹ includes information about cracking in bridge decks with either partial-depth precast concrete panels with a cast-in-place concrete topping or full-depth precast concrete deck panels. Cracking in prestressed and nonprestressed

concrete beams, pier caps, columns, abutments, and pile caps is also addressed.

End-zone cracking in prestressed concrete beams is an infrequent occurrence and often can be prevented by revising the detensioning sequence. Cracks that do occur, however, are controlled through the use of appropriate confinement and splitting reinforcement.

Concrete used in substructures also cracks, but far less frequently than the concrete used in bridge decks. Consequently, there appears to be much less concern about cracks in substructures.

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Dr. Henry G. Russell is an engineering consultant and former managing technical editor of ASPIRESM.



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A BEGINNER'S GUIDE TO ONLINE EDUCATION

by Dr. Michelle Rambo-Roddenberry, Florida A&M – Florida State University

There are many variations of online education, as evidenced by the many terms used in the industry. Online education is a broad term that is typically used by academia to reference the collection of resources (including people and software), and their online implementation, used to facilitate the transfer of knowledge via the internet. E-learning is used largely by industry to reference online learning for continuing education (such as licensure purposes) or for corporate training. These courses are usually geared for self-learning and even self-assessment. Distance learning, or distance education, is about geography—it focuses on the fact that instructors and students are separated by physical space. In addition to geography, instructors and learners can also be separated by time. When curricula are developed for learners to engage in education at a later time, the course is called asynchronous.

An online course is done strictly online and involves no face-to-face meetings. But whether a course is delivered face-to-face or online, the goal is the same:

the successful transfer of knowledge. Instructor facilitation, however, is very different online compared with a traditional course. Online education is not just videoing a chalk- or whiteboard lecture and posting it online for students to watch. Online, a lecture can't be adjusted on-the-fly when students look confused, as it can be in the classroom. An online course requires different strategies about how to engage students and provides opportunities for them to interact with each other and the instructor. In a classroom, I feed off the energy from students, which can be missing in the online environment. In a classroom, I can revive them if they are not paying attention—not so online. But there are clear advantages, as stated earlier, of online delivery. In the following sections, some best practices, tips, and things to consider when designing an online course are suggested.

Best Practices for Online Course Organization

- Have a clear entry point to the course (such as, "Start here") to get students on the right path.

- Be clear about where students need to go next.
- Make links open in a new window.
- Put most recent items on the top of lists or folder items.
- Provide a calendar of assignment due dates.

Things for Instructors to Think About

- Creating an online communication plan: how will you communicate, and will students need special hardware, software, or connections? Consider online chats, discussion boards, journals, and/or video conferences.
- Cheating: how will you deter or prevent it?
- Proctoring: will exams need to be proctored by the university's testing center, by you, or by an authorized person?
- Generating the volume of content: does the university have guidelines to ensure that the course is consistent with the number of credit hours assigned to it? (In a traditional course, this is defined by the number of "contact hours" or hours spent in the classroom.)
- Reusing content: when preparing instructional materials, be careful to avoid dating the materials, so that they can be easily reused in the future. An exception is when referring to a specific version of a code or specification—that should always be done.

Learning Units

A learning unit can be based on a topic or series of related topics. Creating learning units for online delivery is similar to the traditional approach. A suggested process for creating learning units is as follows:

1. Set goals and learning objectives for the course and individual topics. Objectives should describe outcomes

	ONLINE	vs.	TRADITIONAL
For the PROFESSOR			
Preparation	Thoroughness and completeness can be more assured		More subject to miscommunication or mistakes
Content	Pre-determined and structured		Adjustable in the classroom
Time (e.g. to create a single traditional lecture, from this author's experience)	15 hours to develop video. Video can be reused over and over until updates are needed.		Initial delivery: 3-4 hours preparation time. Each semester: 0.5 hours preparation before class + 1 hour in class.
For the STUDENT			
Time (to view content of a single traditional lecture or equivalent)	Watch a 15-minute video and read any supplementary materials		Attend 1-hour lecture + commute time
Repeatability	May rewatch as many times as needed		Cannot rewatch physical lecture unless it was recorded
Convenience / Scheduling	Flexible. Can be self-paced.		Constrained by time and location
Learning Style	Requires independent learning and self motivation		May accommodate dependent learners
For the STUDENT and PROFESSOR			
Interaction	Virtual (online chat; discussion board; journal entries; video conferences; email)		Instant (face-to-face; office hours)

Comparison of a course delivered online with a course delivered by the traditional method from the perspectives of a professor and student. All Figures: Michelle Rambo-Roddenberry.

that are measurable—this is good educational pedagogy for any course, whether face-to-face or online. Objectives should not contain the words learn, appreciate, understand, or know, because these cannot be measured. Instead, consider using words such as identify, explain, solve, interpret, define, or summarize.

2. Develop content that supports the learning objectives. Gather or create supportive visuals (such as photos, sketches, or links to internet content).
3. Create an outline of the learning units.
4. For each learning unit, plan the sequence of study (such as first do this, then read that, then watch this)
5. Decide on delivery media (PowerPoint slides, video, web content, textbook excerpts, or book chapters) for each topic and prepare materials.
6. Decide how to assess student learning.
7. Prepare an engagement activity, such as a discussion board.

Be flexible about the length of a learning unit; the length should suit the content, not necessarily be equivalent to a typical class session. For example, one topic may be suitable for a 10-minute video, while another may need 30 minutes. Or, a PowerPoint presentation may require an hour of review. If a topic will be longer than usual, warn your students ahead of time so they can plan their schedules accordingly.

Get Help

Seek help from others who have taught online, attend workshops offered by your university, or even look for resources online. My university's Office of Distance Learning (ODL) provides excellent support to professors and holds workshops for instructors on the following topics:

- Course organization and content delivery
- Communication and engagement
- Assessment and evaluation

Peer Review

A peer review of your course design can help identify shortcomings. My university uses rubrics from Quality Matters Inc. (QM), an international organization that promotes and improves the quality of online education and student learning by, for example, developing quality



Week 3 – Agencies, References, and Specifications

Enabled: Statistics Tracking

Goals and Outcomes: To be exposed to the agencies that are related to the field of bridge engineering, and to identify their missions and roles. To learn the history of AASHTO and AASHTO Bridge Design Specifications, and to explain why design codes change.

Sequence of Study:

1. First, listen to the short AGENCIES AND REFERENCES audio file. Nothing technical here. Just a quick introduction to the week.
2. Then, review the AGENCIES (PDF) file at your own pace. Explore websites for the agencies to find out more about them. You might stumble upon something interesting.
3. In the Assignments folder, complete the AGENCIES Assignment. (It's an online quiz, but you may use the Internet to answer the questions.)
4. Next, review the REFERENCES (PDF) file at your own pace.
5. Then, view the BRIDGE SPECIFICATIONS video.
6. By **midnight on Sunday, September 15**, Reply to "Discussion Board, Week 3" Forum and view others' posts.

Example of an online module for a bridge engineering course.

standards and evaluation tools and procedures. QM has a faculty-centered peer-review process that is designed to certify the quality of online and blended courses. It focuses on course design and the student learning experience, not on faculty performance or delivery. The QM rubrics assess items such as course learning objectives, assessment and measurement, instructional materials, and learner interaction and engagement.

My Experience

To prepare for the facilitation of my first online course, I attended workshops on online learning held by my university's ODL. I decided to prepare scripted, voice-over PowerPoint presentations on all of the course topics, rather than point a video camera at me lecturing with a whiteboard. I gathered all of my books, references, specifications, and course notes, spread them over the dining room table, and got to work organizing the lectures.

For several weeks, I prepared one lecture at a time. It took about one hour to prepare the slides and script for each minute of PowerPoint presentation. However, I found that a 15-minute PowerPoint presentation covered the same material that I would normally cover in an hour-long lecture. (I'm probably slow; try it for yourself.) Even though the PowerPoint-presentation recording took a long time to prepare, I figured I was saving my students time by delivering content efficiently.

Using the QM rubrics, my university's ODL provided feedback: "Good features to keep: Learning objectives are nicely written and measurable. Nice mix of interesting assignments that are also practical and effective. The videos are

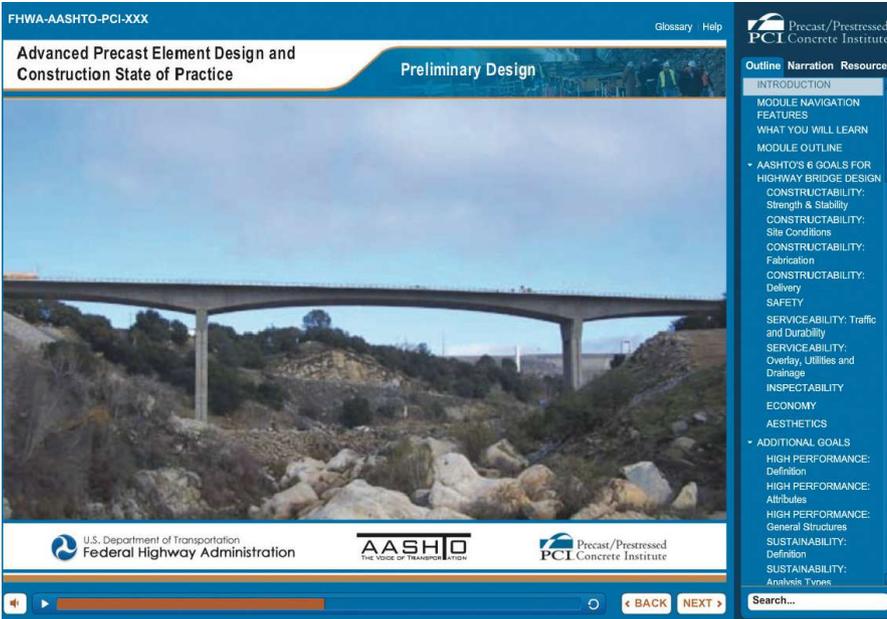
well narrated with a good speaking voice and rate. To improve: Make sure that discussion board assignments are included on a regular basis so that students have an opportunity to interact with each other as well as with you." (My aversion to social-media-type communication was exposed.)

A Blended Approach

My experience with graduate students is that they want to learn more direct applications of principles. Their education has progressed well beyond memorization, learning basic concepts, or simply solving problems using equations. They are less tolerant of ill-defined expectations than undergraduate students are.

After several years of university teaching, I no longer feel obligated to talk incessantly and fill up the whiteboard for every lecture. There are other ways a teacher can facilitate knowledge. Instead, sometimes I will ask students to do an in-class activity. It feels like less material is being covered, but because the students are challenged to think on their own, their understanding is deepened. It's better for the student, and it's easier on the teacher. Having students work together in the classroom means that I can guide and direct them to understanding, and I leave class knowing better what they did and didn't understand.

This semester, in my face-to-face Bridge Engineering course, I provided students with some of those voice-over PowerPoint videos. These videos either provided extra content on nontechnical topics such as bridge aesthetics (worthy of pajama viewing), replaced face-to-face lectures when I was unable to attend class due to travel for



Screenshot of a "Bridge Specifications" video for students to view as part of a course module.

research, or replicated my face-to-face lectures for particularly complex topics. This would be classified as a web-enhanced course or blended course.

The following is some feedback based on students' comments about the teaching strategies used in the course:

- They enjoy having time to ponder and discuss topics that are presented on the whiteboard.
- They like a slower pace that allows for deeper learning.
- They dislike intensive taking of notes. They want to focus on processing the content, but say they have trouble keeping up with writing notes at the same time. However, they also dislike it when professors deliver lectures only with a PowerPoint projection.
- They learned from the in-class exercises (in which I talked less and facilitated more). They enjoyed seeing how other students approached problem solving. They say this also enabled them to self-assess their learning—to see if they could solve the problem on their own, rather than having it all presented to them on the board. (I was afraid they would ask for a refund because I didn't talk as much.)
- Students overwhelmingly said they prefer face-to-face courses to strictly

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online courses for several reasons. They can ask questions on-the-spot, as soon as they come to mind. They reported a tendency to procrastinate a lot more with online classes. Rather than participating in online discussion boards, such as commenting on other students' work, they would rather work together in class.

- They very much enjoyed having a face-to-face lecture along with a prepared video lecture. The repetition, especially on complex topics, was helpful.
- They prefer videos that are 30 minutes or less.
- They did not watch videos for which I did not give an assignment. I don't know why that surprised me. (I'm blessed that my students are honest with me, but cursed because now I know the truth: ignorance really can be bliss.)

Tips for Preparing Voice-Over PowerPoint Lectures

Having now prepared many voice-over PowerPoint lectures, I offer the following tips:

- Spend time creating a well-prepared script before recording. This can greatly improve the learner's experience. To avoid sounding scripted during narration, I pretend that I'm talking to a student sitting beside me—the kind of student who would normally sit in the front of the class and ask thoughtful questions.
- Use a good microphone (I use a Blue Yeti USB microphone). Consider using a pop filter: it won't rid you of a southern accent, but it will improve sound quality. Don't use a karaoke mic; those never sound good.
- Make sure that crickets aren't chirping or dogs aren't barking outside during recordings.
- Avoid recording late in the day when your voice is tired. Drink water before narration and during pauses.
- Smile while narrating the script. Research shows that you can hear a smile.
- Invest in a good screen-capture software such as Camtasia. I use it to capture PowerPoint slides and transitions, as well as audio. Camtasia is easy to use and it converts files to a video format.

- If you want to go whole hog and create a professional module that includes embedded quizzes, outlines, narration text, and student interactivity features (such as clickable objects and pop-up windows), consider using software such as Adobe Captivate or Articulate Storyline to develop your modules. This can help enhance student engagement.

The preparation for teaching or facilitating an online course is different than for traditional face-to-face classroom delivery. Many of my tips can be applied to video conferences, professional presentations, or meetings with clients. As with many things, organization and preparation are key elements for a successful online teaching experience. 



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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://www.nap.edu/download/24689>

This is a link to download a PDF of *Control of Concrete Cracking in Bridges*, a synthesis report recently published by the National Cooperative Highway Research Program (NCHRP), and referenced in the Safety and Serviceability article on best practices to reduce cracking in bridge decks.

<http://www.earthcam.net/projects/bayonnebridge/?cam=pano>

This is a link to a panoramic view of the Bayonne Bridge project that shows the difference in elevations of the old and new approaches. The Bayonne Bridge is featured in both a Project article on page 20 and a Concrete Bridge Technology article on page 28.

<http://www.gcpci.org/index.cfm/technical/pcef>

This is a link to the website of the Precast Concrete Economical Fabrication (PCEF) Committee that has information on materials, cross sections, and projects using PCEF bridge elements. PCEF elements are mentioned in the article on page 6 featuring STV.

<http://www.enr.com/articles/12218-yadkin-river-bridge-project-delivers-timely-replacement-of-aging-structure>

This is a link to an online article about the Yadkin River Bridge that appeared in *ENR*. The bridge was designed by STV, the engineering firm featured in an article on page 6.

<http://www.aspiremagazinebyengineers.com/i/306966-winter-2008/43>

This is a direct link to the *ASPIRE*SM Winter 2008 article "Precast Enables Environmental Avoidance," that inspired the solution to the site challenges of the El Salto Falls Street Bridge that is featured in the Project article on page 16.

<http://www.aspiremagazinebyengineers.com/i/768999-winter-2017/13>

This is a direct link to "Long Key Bridge Pier Replacement," that appeared in a Project article of the *ASPIRE* Winter 2017 issue. Details of the V-pier replacement are in the Concrete Bridge Preservation article on page 50.

<http://www.wsdot.wa.gov/publications/manuals/fulltext/M23-50/BDM.pdf>

This is a direct link a pdf of the Washington DOT *Bridge Design Manual (LRFD)* which contains a chapter solely dedicated to accelerated bridge construction methods, techniques, and design details. This document is featured in a Construction Bridge Technology article on page 32.

http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/2012/DOI_Articles/JL-Fall-2012-8.pdf

This is a direct link to the Fall 2012 *PCI Journal* article "Accelerated bridge construction in Washington State," which describes the development and implementation of the precast concrete bent system that appears in the Construction Bridge Technology article on page 32.

<https://www.nap.edu/catalog/22971/blast-resistant-highway-bridges-design-and-detailing-guidelines>

This is a link to the NCHRP Report 645 *Blast-Resistant Highway Bridges: Design and Detailing Guidelines*. Guidance on the design

of bridge elements and materials to lessen probable damage from terrorist attacks is the topic of the FHWA article on page 48.

<http://www.startribune.com/franklin-avenue-bridge-makeover-and-detours-expected-to-end-by-labor-day-weekend/378903411/#>

This is a link to an article that appeared in the Minneapolis StarTribune describing the importance of the Franklin Avenue bridge renovation to the local neighborhood and the accelerated construction methods used. The Franklin Avenue bridge is featured in a Project article on page 24.

OTHER INFORMATION

<http://www.astmnewsroom.org/default.aspx?pageid=4250>

This is a link to information on the revision of ASTM A416/A416M, *Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete*.

<http://nap.edu/24779>

This is a link to the recently published NCHRP Research Report 848: *Inspection Guidelines for Bridge Post-Tensioning and Stay Cable Systems Using NDE Methods*. The report describes nondestructive evaluation methods for assessing the condition, including corrosion, section loss, breakage, grout conditions, voids, and water infiltration, of in-service post-tensioning and stay cable systems.

https://bookstore.transportation.org/collection_detail.aspx?ID=149

This is a link to the table of contents and information on ordering and updates for the publication *Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and AASHTO Provisional Standards*. This is now a web-based publication and no longer available as a printed book.

<http://www.trb.org/Main/Blurbs/175864.aspx>

This is a link to the final report for NCHRP Innovations Deserving Exploratory Analysis (IDEA) Project 174, *Enhanced Performance Zinc Coating for Steel in Concrete*. A reinforcing bar with a thermal zinc-diffusion coating was evaluated for corrosion protection.

<http://www.dot.state.mn.us/research/TS/2017/201701TS.pdf>

This is a link to a technical summary released by the Minnesota Department of Transportation on a system that analyzes accelerometer data from sensors on the I-35W St Anthony Falls Bridge. The data shows how the concrete structure bends and deforms in response to traffic loads, wind, and temperature changes.

<http://www.register.extension.iastate.edu/uahpc2016/attendance/interactives>

This is a link to the Interactive Panel Final Reports issued from the First International Interactive Symposium on Ultra-High-Performance Concrete, held in 2016. The next symposium will be held in 2019 in Albany, New York.

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SH-55 over North Fork Payette River
McCall, Idaho



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WWW.PCI.ORG

Photos: Upper photo courtesy of Dimensional Innovations,
lower photo courtesy of ITD Staff.

Changing Perceptions

WEST VIRGINIA'S REPUTATION FOR BUILDING STEEL LONG-SPAN BRIDGES HAS BEGUN TO CHANGE AS IT GAINS SUCCESS WITH INNOVATIVE CONCRETE DESIGNS—AND REAPS THE TAX REVENUE BENEFITS

By Ahmed N. K. Mongi, West Virginia Department of Transportation

The East Huntington Bridge, opened in 1985, features a precast, prestressed concrete cable-stayed design with only one tower and main spans of 900 and 608 ft. The bridge's structural system is lighter than earlier concrete cable-stayed bridges and was only the second one of its kind to be built in the United States. All Photos: West Virginia Department of Transportation.



West Virginia has long been known for its steel bridges. This is ironic, as more than half of the state's bridges (about 52%) are built with concrete girders, and a successful program has been developed for rapidly replacing short-span bridges using standardized concrete beams. But, the West Virginia Department of Transportation (WVDOT) has been less successful in letting contracts for long-span segmental concrete spans. Now that is beginning to change as new designs have created successful bridges for WVDOT and contractors. An added benefit from building with concrete to the state is greater tax revenues.

The West Virginia Department of Transportation operates with a central office, which handles larger, more complex structures, and 10 district offices. Each district bridge office includes engineers, designers, inspectors, and maintenance crews. For some time, each team has used adjacent concrete box-beam girders standardized for lengths of up to 100 ft. The team selects the length of the bridge from a chart and specifies the designated beams.

This approach allows districts to quickly create drawings for shorter-length bridges, leading to short-span projects being constructed with concrete box beams by default. Each district completes two or three such projects each year. Districts used to have on-staff construction teams, but today that work is performed by outside contractors.

Consultants work on larger projects when WVDOT is unable to handle the workload or a complicated design is required. In many cases, regardless of who designs the project, spread boxes and I-beams are used for concrete designs. Of the concrete bridges, which account for about 3711 out of the 7187 total, approximately 1420 (38%) feature reinforced concrete, while 2291 (62%) use prestressed concrete, mostly in box-beam designs.

Cable-Stayed Bridges

Consultants designed two West Virginia's most dramatic concrete bridges, both cable-stayed designs. The East Huntington Bridge, opened in 1985, features precast, prestressed concrete girders with main spans of 900 and

608 ft supported by a single concrete tower. Only the second of its kind in the United States when built, it features high-strength prestressed concrete edge beams and deck with steel floor beams in a hybrid arrangement. The approach structure is a cast-in-place single-cell segmental concrete box girder erected using balanced-cantilever construction.

A more recent cable-stayed bridge, the Bridge of Honor (also known as the Pomeroy-Mason Bridge) over the Ohio River was built in 2008 and features a cast-in-place concrete segmental design (see article in Summer 2008 issue of *ASPIRE*SM). It is somewhat unique in that it was designed and built by the Ohio Department of Transportation and then turned over to WVDOT for operation and maintenance, owing to an earlier agreement on interstate construction and to its location, primarily in West Virginia.

Steel designs were used previously for long spans for several reasons. Foremost is that contractors typically were more comfortable with steel for longer crossings, which was a difficult mindset to break. WVDOT designers have provided concrete alternatives in many instances, but in the past the steel option typically was chosen during the bidding process.

Kanawha River Bridge Shifts Paradigm

A new paradigm has been created with the construction of the Kanawha River Bridge, completed in 2010, which produced a record span for a cast-in-place segmental box-girder structure (see article in Winter 2009 issue of *ASPIRE*). The 2975-ft-long concrete design with a 760-ft-long



The Bridge of Honor over the Ohio River is a cast-in-place segmental concrete cable-stayed bridge designed and built by the Ohio Department of Transportation and then turned over to the West Virginia Department of Transportation for operation and maintenance.

main span was evaluated as the least expensive option, owing to the complex geometry.

When local contractors became aware of the design, they convinced WVDOT management to allow a steel alternative to be considered. But in the bidding stage, the concrete design still won because it was more cost-effective. It features spans of 144, 247, 295, 295, 460, 760, 540, and 209 ft. Spans 1 through 5, 7, and 8 have curved alignment, including a circular curve with a 1910-ft radius and a spiral transition. The box girder is post-tensioned in the longitudinal, transverse and vertical directions.

With this success, designers and contractors have seen the long-span effectiveness of concrete. They also can take advantage of a number of competitive suppliers in the state to provide expertise and components, as well as skilled

laborers in the tristate area to work on the projects.

Concrete designs provide significant benefits for projects using accelerated bridge construction (ABC) techniques, as components can be fabricated away from the site and then delivered once the site is ready. WVDOT has used precast concrete deck panels on smaller bridges as well as precast concrete abutments and wing walls in addition to beams. Also, more ABC projects are being designed with concrete, as the material fits very well with faster schedules.

In-State Tax Benefits

An additional part of WVDOT's interest in concrete designs comes from the added tax revenues. When a project is bid with concrete components, they are generally fabricated in the state, so the business and occupation taxes remain in the state. With a steel design, manufacturing occurs out of state, eliminating millions of dollars in revenue for materials and labor, and generating no job opportunities for the citizens of West Virginia.

Workers are guaranteed to be paid the prevailing wage for fabricating concrete components in West Virginia, which cannot be guaranteed when steel components are fabricated in other states. When evaluating various materials' benefits in a larger context, the tax revenues and job creation provided by concrete materials are very compelling.

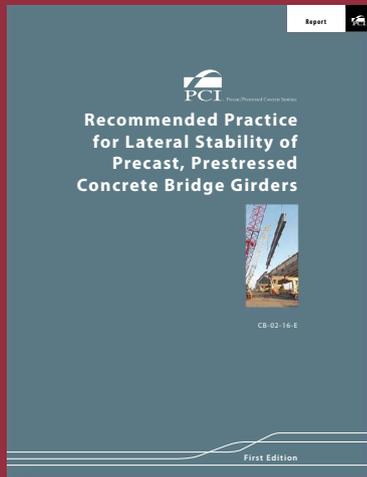
Concrete designs also were aided by changes to state laws approximately nine years ago, which allowed design-build delivery methods to be used. This led to a broader range of concepts and encouragement of innovations that save time and money. In some cases, these designs began as steel designs and were value-engineered into concrete designs.

A number of concrete bridges have been completed as design-build projects, including the Van Metre Ford Bridge, which replaced a historic stone bridge (retained as a pedestrian



The concrete beams of the Coopers Creek Bridge were long and would have been heavy, but the design-build team specified lightweight concrete to both reduce the weight and minimize the crane size.

Announcing The First Edition of



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 on line
at www.pci.org/epubs



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The Van Metre Ford Bridge (above and below), a design-build project, contains prestressed concrete hybrid bulb tees with a 40-in.-wide bottom flange that allows more prestressing strands to be used.



bridge). The bridge uses a prestressed concrete hybrid bulb tee developed from a Kentucky design, that has a 40-in.-wide bottom flange. The design allows more prestressing strands to be included, providing a shallower depth than is possible with standard girder shapes. This unique bulb-tee cross section creates opportunities where longer spans and higher under-bridge clearances are needed.

The bulb tees were made with 9-ksi concrete, which provided added capacity. Precast producers say they can provide this concrete strength routinely, and WVDOT expects to use it more often now that there is the option of spanning longer distances with a shallower girder to create the largest waterway opening.

Another design-build project, the Coopers Creek Bridge, featured 161-ft 6-in.-long prestressed concrete beams that would have been very heavy so the designers specified lightweight concrete to reduce the weight as well as to minimize the crane size.

These advances are creating more opportunities for concrete designs that help resolve issues

and build bridges more quickly and more cost effectively. WVDOT's goal is to encourage innovation and maximize the potential for concrete designs to ensure every creative concept is considered. **A**

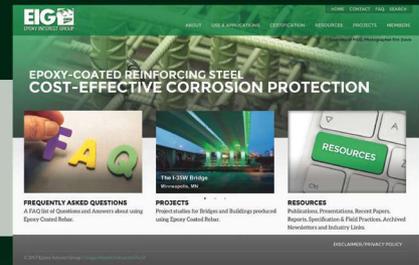
Ahmed N. K. Mongi is quality assurance/quality control unit leader in the In-House Design Section of the Engineering Division of the West Virginia Department of Transportation's Division of Highways in Charleston, W.Va.

EDITOR'S NOTE

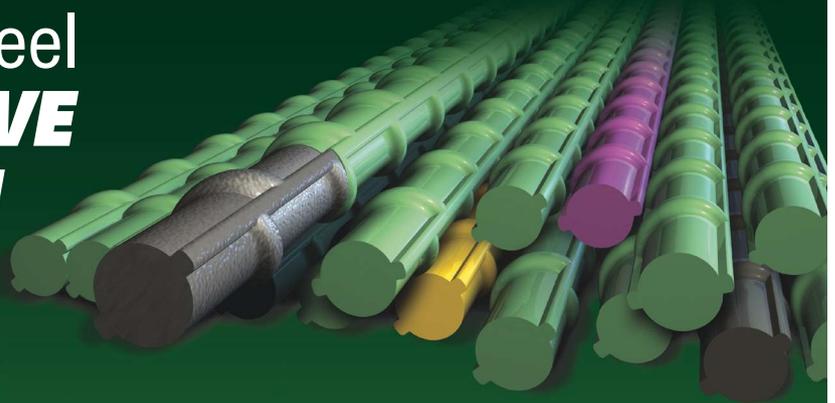
There are two articles about the Design and Construction, respectively, of the East Huntington Bridge. Please see the January-February 1987 and November-December 1987 issues of the PCI Journal.



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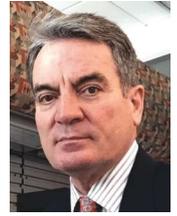


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FHWA Unveils New Bridge Security Design Manual



by Steve Ernst, Federal Highway Administration

The Federal Highway Administration (FHWA) recently completed the first edition of its *Bridge Security Design Manual*.¹ The manual was developed through an FHWA indefinite delivery, indefinite quantity contract with HDR Engineering and written by subcontractor PEC Engineering. It is available on the FHWA website.

The manual provides information for structural engineers, planners, owners, and others to incorporate effective strategies in bridge projects and make highway systems resilient against terrorist threats. These threats

have been a growing concern in the United States since the September 11, 2001, attacks, and it has been shown by the Mineta Institute² and others that transportation structures are among the most popular targets for terrorist organizations. While previous infrastructure security research and practice have focused primarily on buildings, the limited bridge-specific design guidance suggests that bridges may not be well protected against the common loadings these terrorist threats can impart to bridge components. “The primary objective of this bridge security design manual is to present state-of-the-art guidance on bridge-

specific security planning, extreme loading phenomenology and characterization, and protective design strategies to be used by the highway bridge community in terrorist threat vulnerability assessments of existing bridges, resilient design of new bridge construction, and emergency planning efforts.”¹

The manual covers a broad range of topics, including security planning, material performance, blast phenomenology, mechanics of structural elements, dynamic response of structures, protective design guidance, example designs for several component types (such as concrete towers), and the use of the software tool, Anti-terrorism Planner for Bridges (ATP-Bridge). The chapters covering these topics are fairly well self-contained. For example, the reader who is interested in understanding protective design for a concrete tower can use that chapter and relevant sections on loading, materials, mechanics, and response to gain a reasonable understanding of how to design a resilient tower.

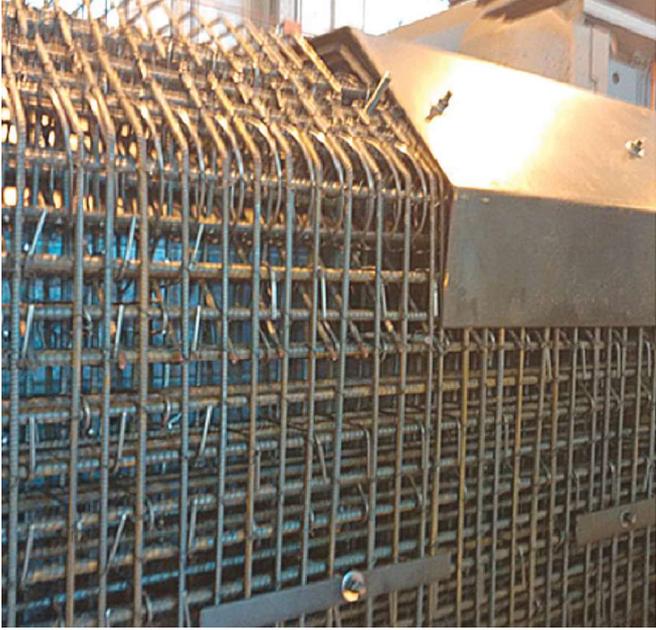
Of particular interest to those who are new to this topic may be the chapters on planning, materials, and blast phenomenology. This information explores these topics from the bridge designer’s point of view and provides background and fundamental principles that are carried forward into specific examples of protective design.

The chapter on ATP-Bridge stands alone to describe the use of the software design tool developed by the U.S. Department of Homeland Security and the authors of the manual. ATP-Bridge is a practical, engineering-level software program capable of predicting the response and anticipated damage of critical bridge components subjected to a variety of threat scenarios. ATP-Bridge features flexible software architecture designed to be continuously updated with state-of-the-art research and intuitive, user-friendly functionality that aligns with practice. The protective measures described in the manual use

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 - Dynamic Analysis of Reinforced Concrete Columns
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Table of contents from the *Bridge Security Design Manual*. All Figures and Photos: Federal Highway Administration.



Reinforcement cage for a hollow concrete tower designed to resist blast loading.

Detail of reinforcing steel cage for hollow concrete tower designed to resist blast loading.

the same state-of-art information from research and practice already incorporated in ATP-Bridge, so users of this manual can expect consistent alignment of design calculations and results. While ATP-Bridge might not be sufficient for all evaluations (for example, dynamic response), it is a very good predictor of damage from spall and breach, and the manual clearly describes supplemental design processes and tools to guide planners and designers to other resources.

One topic covered in the manual is protective design guidance for reinforced concrete towers; an excerpt from this chapter is included here:

The chief protective design objective for blast-loaded RC [reinforced concrete] towers is to mitigate extensive local damage to individual RC tower panels such that gross loss in gravity-load carrying capacity and consequent collapse of the

bridge is prevented. To achieve this chief objective, a recommended design procedure consisting of the following steps should be carried out:

- *Blast load characterization*
- *Component-level analysis and design of most severely loaded RC tower panel(s)*
- *System-level analysis to evaluate potential for collapse of bridge*

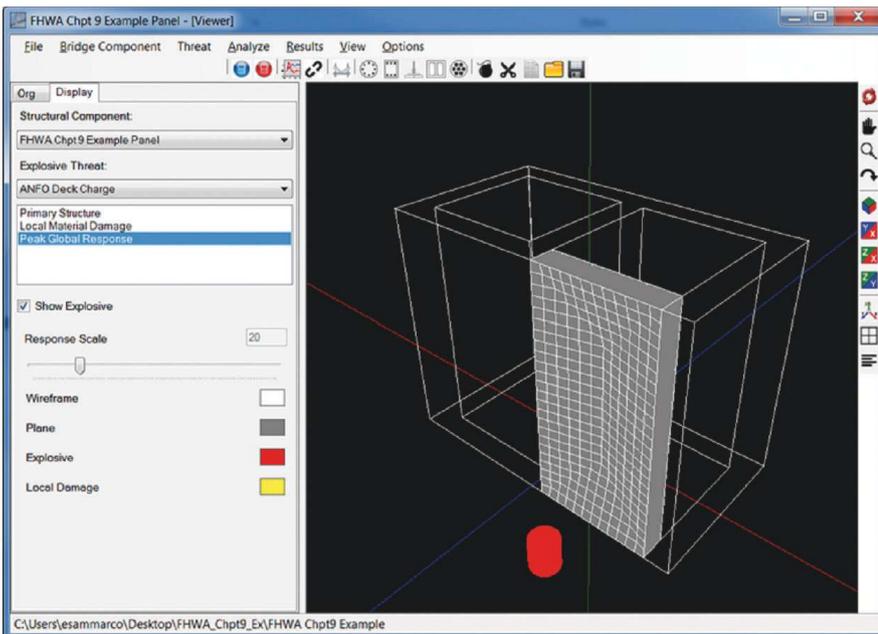
The example goes on to describe each of these steps in detail, including an analysis approach that first makes use of ATP-Bridge, then describes a potential alternative component-level dynamic analysis tool for preliminary design, and recommends that a high-fidelity finite element model be developed for the final nonlinear dynamic analysis. Though the use of specialized finite element software is not part of the manual, the steps and modeling techniques

that a designer should employ are outlined to provide useful design guidance. Preliminary design using ATP-Bridge may also prove useful in planning or preliminary project development to establish good cost estimates and refined contract performance criteria.

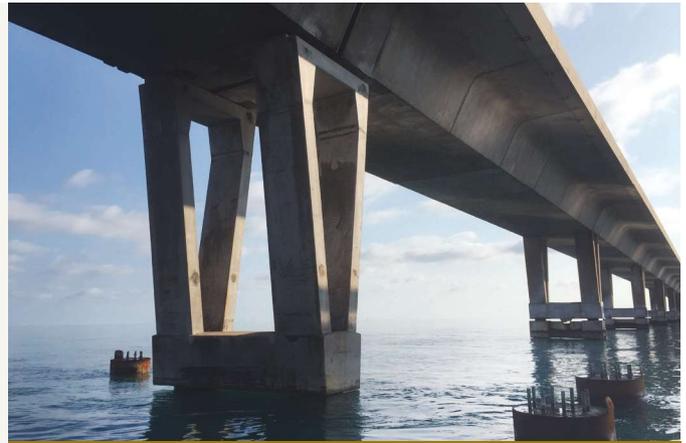
The *Bridge Security Design Manual* is intended to be both a resource for broad audiences to better understand bridge security and a reference tool to design protection into bridges and to enable the highway systems they connect to function at a high level under a variety of threats. It makes use of the latest technology and research, including the ATP-Bridge tool. It is expected that the manual and the analysis software will be routinely updated to incorporate future research and state-of-the-practice for security design. The manual is available on the FHWA website: <https://www.fhwa.dot.gov/bridge/security/hif17032.pdf>. ATP-Bridge is available, with restrictions, from the U.S. Army Corps of Engineers Protective Design Center: <https://pdc.usace.army.mil/software/atp4bridges>.

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1. Federal Highway Administration (FHWA) and PEC Engineering. 2017. *Bridge Security Design Manual*. <https://www.fhwa.dot.gov/bridge/security/hif17032.pdf>.
2. Jenkins, B. M., and L. N. Gersten. 2001. *Protecting Public Surface Transportation against Terrorism and Serious Crime: Continuing Research on Best Security Practices*. MTI Report 01-07. San Jose, CA: Mineta Transportation Institute (MTI).
3. Sammarco, E. L. 2014. "Development of Simplified Dynamic Response Models for Blast-Loaded Bridge Components." PhD diss., University of Texas at Austin. 



ATP-Bridge three-dimensional graphics window showing blast source and response of panel of a two-cell reinforced-concrete tower.



New V-pier installed. The 48-in.-diameter drilled shafts used for the temporary support system installation can be seen. These were later removed to 1 ft above the mudline.

Replacement of Long Key Bridge V-Piers

by James Charles, John Meagher, Tom Charles, and Wayne Wheeler, Johnson Bros. Corporation

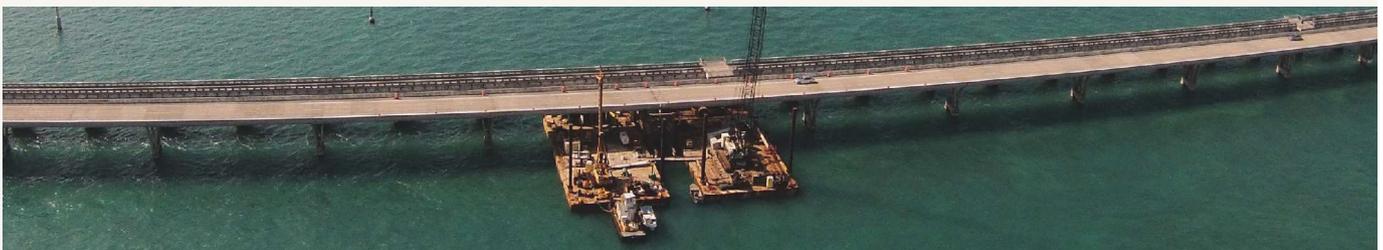
Replacement of the Long Key Bridge V-piers presented several challenges that were overcome during the construction phase of the project. As general contractor, Johnson Bros. Corporation, a Southland Company, used innovative construction techniques to provide a quality repair while keeping safety the top priority.

The project crosses the Long Key Channel, which is within designated Outstanding Florida Waters (an article in the Winter 2017 issue of *ASPIRE*SM describes the development and design of this project). Restrictive environmental permits regulated barge activities and required all spud (barge anchor) locations to be surveyed, logged, and reported. Barge spud locations, along with drilled-shaft locations, were required to be premarked and cleared of endangered benthic (sea floor) resources prior to the arrival of barges. To satisfy construction requirements, the general contractor coordinated with the permitting agencies for modification of the permits to reorganize the areas allowed for spudding. The project was successfully completed without any violations of the spudding restrictions or permit requirements.

Transportation Logistics

The precast concrete V-piers were cast in Tampa, Fla., by Standard Concrete Products and delivered to the jobsite by

specialty trucks. The general contractor looked at several options for the transportation of the monolithic precast concrete V-piers. The simplest approach was to transport the piers to the site via barge and tug, but due to safety concerns an alternate approach was pursued. The general contractor worked with McTyre Trucking and the precast concrete producer to develop a plan to mobilize the piers with specialized trucking. The 135-ton, 16-ft-wide piers required special permits to be delivered via U.S. 1 through the Florida Keys. Blanket permits are not available past Homestead, Fla., and wide-load permits are restricted past Key Largo, Fla., so coordination with the general contractor, the trucking company, the engineer and the construction inspector (Parsons Brinkerhoff), and the Florida Department of Transportation (FDOT) was required to mitigate the concerns and risks associated with the delivery. The Channel 5 Bridge and the Long Key Bridge were required to be closed to traffic while the piers were delivered, so all deliveries occurred between midnight and 2:30 a.m. The Long Key Bridge was closed for only 30 minutes for each unloading operation, which consisted of installing the spreader beams, properly rigging the V-piers, safely lifting and moving them by crane to the barge below the bridge, and disassembling the specialty trailer so it could move off the bridge. All 12 piers were unloaded without incident or unauthorized traffic closures.



Aerial view of the barges in position for V-pier installation. All Photos: James Charles.



Temporary support system in place and removal frame installed on existing V-pier. Jacking system can be seen.



V-pier being lowered from Long Key Bridge to the construction barge at night. Note holes for dowels to drilled shafts.



New V-pier being lifted and placed onto the temporary support system. Hydraulic jack and roller assembly is mounted on the column legs.

Construction

The temporary support system (TSS) was supported by four 48-in.-diameter drilled shafts for each pier. These were installed using a full-containment system to prevent any discharge of excavated materials or turbid water into the waters of the sanctuary. Due to the local scarcity of structural ready-mix concrete suppliers approved by the FDOT in the Florida Keys, as well as the distance of the plants from the project, concrete was difficult to obtain. A tremie system was fabricated to allow rapid discharge of the concrete into the shafts to reduce on-site truck time. By eliminating the need for boom-pump trucks, the tremie system also allowed concrete to be placed from the Long Key Bridge superstructure during the daylight hours without lane closures. This enabled a more flexible pour schedule while also reducing the impact on the traveling public.

A stanchion system was designed and installed on the barges to allow the TSS to be assembled in two halves prior to mobilization to the piers. Each half of the TSS was hung from the two sides of the barge, at which time the barge was pushed into place next to the drilled shafts. The TSS was then lifted onto the shafts using two cranes. A 45-ton rough-terrain crane had to be used on the front of the barge so that its boom could be lowered to get underneath the bridge and then boomed up between the newer Long Key Bridge and the historic Flagler East Coast Railroad Bridge, which is now used as a fishing pier. The TSS was then lifted off the barge brackets and secured on top of the drilled shafts with the embedded anchor rods. The barge would then move to the other side of the pier and repeat the process for the second half. This process eliminated the need for the TSS to be fully disassembled and reassembled for each pier, reducing the set-up and break-down times.

Removal of the existing V-piers was facilitated by a removal frame—designed by the general contractor’s specialty engineer, A2B Engineering—that supported the four column legs that formed the V. After jacking operations removed the compressive stresses on the columns, the legs were chipped out, and cut at locations under the superstructure and just above the pier cap at the hinge points. They were then rolled out in pairs and lifted to a demolition barge for removal. The pier cap was separated from the existing 42-in.-diameter drilled shafts by wire sawing, then rolled out and lifted by crane onto the demolition barge. The removal frame allowed the existing piers to be disengaged and then removed from under the Long Key Bridge superstructure with only 15-minute traffic closures during the actual jacking operations.

The replacement precast concrete V-piers were required to be positioned with high precision in relation to the existing drilled shafts and the existing Long Key Bridge box-girder superstructure. Four pedestals cast integrally at the top of each precast concrete V-pier needed to be placed directly underneath the diaphragms inside the substructure’s expansion joint segments, while also aligning the 16 dowel holes in the pier cap with the reinforcement cages of the existing drilled shafts. Alignment of the precast pier dowel holes with the existing drilled shaft reinforcement cage was critical to allow coring of the dowel holes through the pier cap into the drilled shafts without damaging the structural integrity of the shafts or damaging the coring equipment. The V-pier was placed on four hydraulic jacks mounted on high-capacity rollers. This allowed the pier to be rolled into place and then adjusted in small increments to the precise position.

After alignment of the V-pier and preparation of the existing drilled shafts, custom-fabricated aluminum grout forms were clamped to the top of the existing drilled shafts and adjusted to exact elevation. The drilled shaft tops and cored dowel bar holes were cleaned, then the V-pier was lowered by hydraulic jacks onto a seal on the top of the clamps. Once the clamps and V-pier were sealed, grouting was begun. After the grout reached its design strength, neoprene bearing pads were slid into location between the pedestals and the bridge superstructure. The overall movement of the superstructure was less than 1/8 in.

The project was completed safely and successfully, allowing the Long Key Bridge, the only land access to the Lower and Middle Florida Keys, to remain open during construction. ▲

James Charles is a project engineer, John Meagher is vice-president of operations, Tom Charles is an area manager, and Wayne Wheeler is general superintendent, all with Johnson Bros. Corporation, a Southland Company, in Orlando, Fla.

EDITOR’S NOTE

For more information on the Long Key Bridge V-pier replacement, see the Winter 2017 issue of ASPIRESM.



AASHTO LRFD Bridge Design Specifications: Combined Shear and Torsion

by Dr. Oguzhan Bayrak, University of Texas at Austin

Within the context of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*, and as it applies to concrete bridges, elements must be designed for combined shear and torsion. In general terms, there are two broad categories of torsion: St. Venant torsion and warping torsion. In cases governed by St. Venant torsion, there is no distortion within the plane of twisting; however, out-of-plane distortion (that is, warping) is not restrained and does not vary along the length of the structural member under consideration. As the name implies, in cases where there is distortion within the plane of twisting, warping torsion must be considered. Open sections, such as horizontally curved U-beams, are subjected to both forms of torsion. Closed sections that essentially have a "tubular" appearance are primarily subjected to St. Venant torsion. Increased member slenderness, and gradual application of torque (such as that introduced by self-weight of the member) all lead to a greater St. Venant contribution.

Understanding the displacement/deformation fields associated with both St. Venant and warping torsion enables the structural designer to make the right choices during the analysis stage, such that models conducive to producing the expected deformation patterns can be selected. Whereas some analysis tools consider the aforementioned facts

implicitly, others require selection of element types and mesh density that are consistent with the problem at hand.

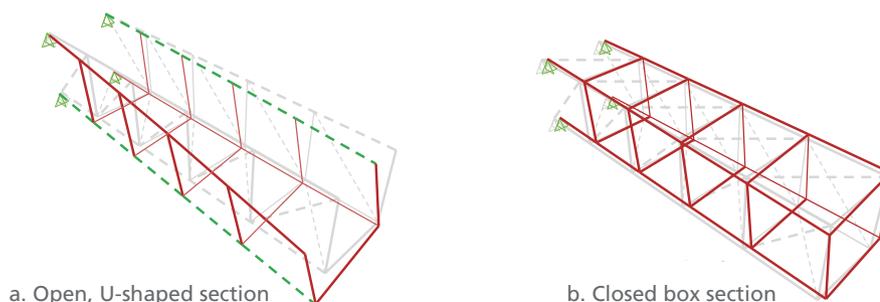
Another important aspect of design for the combined effects of shear torsion relates to the understanding of torsional cracking and its implications. Upon cracking, the torsional stiffness of a reinforced concrete element reduces drastically. This reduction may be as large as 90%. In cases where the structure is statically indeterminate, redistribution of forces upon torsional cracking is possible when other load paths are present to maintain stability (compatibility torsion; see this column in the Summer 2016 issue of *ASPIRE*SM). In such cases, the redistribution of forces implies that torsional moments applied to a member are released (that is, torque is reduced down to the level of cracking torsion) through the formation of the torsional hinges and the released torsional moments may be converted into additional bending moments and associated shear forces that must be resisted by other elements. This leads to an understanding that structural details, such as the use of well-anchored reinforcing bars, and proper use of crack-control reinforcement are essential to ensure acceptable serviceability of the regions in which torsional cracking is expected.

In statically determinate cases and statically indeterminate cases where there is equilibrium torsion, the redistribution of internal forces is not possible and torsional resistance of the element is

essential to maintain equilibrium. Based on the fundamental principles of Modified Compression Field Theory, the *AASHTO LRFD Bridge Design Specifications* allow for the calculations of resistance under the combined effects of shear, torsion, and flexure, as discussed in this column in the Spring 2017 issue of *ASPIRE*. AASHTO LRFD provisions for cracking torsion (that is, Eq. 5.7.2.1-4 and 5.7.2.1-5), are based on the "thin-walled tube" analogy and the application of pure torsion. These equations, by definition, do not take into account the warping component of the torsion or other load effects, if present.

We must remember that in cases where significant torsion is introduced abruptly into an element, for open sections subjected to torsion and having a relatively short length, the effects of warping can be significant and should be accounted for.

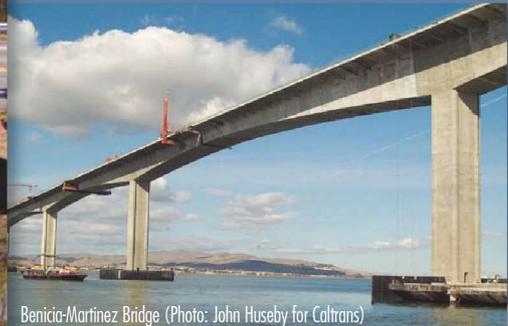
In cases where combined effects of shear and torsion are present, it is prudent to calculate the principal tensile stress within the webs of the concrete elements under consideration and obtain an estimate for the cracking torsion on that basis. Torsion and shear may have additive stresses causing diagonal tension in one of the webs of a box or U beam, and as such, the combination of these effects may exacerbate diagonal cracking and associated redistribution of internal forces. In short, design for combined shear and torsion requires comprehensive understanding of structural behavior and of the basis of the code expressions. 



Isolated cantilever beam in pure torsion. Figure: Hossein Yousefpour.



Harper Creek Bridge (Photo: Whitman, Reardon & Associates, LLP)



Benicia-Martinez Bridge (Photo: John Huseby for Caltrans)

Lightweight concrete solves a variety of design challenges

The article about the Route 198 (Dutton Road) over Harper Creek in rural Virginia that appears in this issue of *ASPIRE*SM is an interesting example of how lightweight concrete can be used to solve challenges for bridge designers. The most economical solution for rehabilitating the bridge was determined to be replacing the superstructure and reusing the existing foundations. Using lightweight concrete for the girders, deck, and railings made this possible by reducing the weight of the new structure and also addressed durability concerns about the brackish water being so close to the superstructure.

While lightweight concrete provided a successful solution for this short-span, low-traffic bridge, it can also provide solutions for long-span, high-traffic bridges such as the I-5 Bridge over the Skagit River (see the Winter-2014

issue of *ASPIRE*) and the Benicia-Martinez concrete segmental box girder bridge. For this 6500-ft-long bridge, which was featured in the Summer 2007 issue of *ASPIRE*, lightweight concrete was used for the box girder to significantly reduce foundation costs by reducing seismic loads.

These bridges demonstrate that lightweight concrete is a valuable and effective design tool for bridges of all sizes and types. For more information on lightweight concrete in bridges, visit www.ecsci.org.



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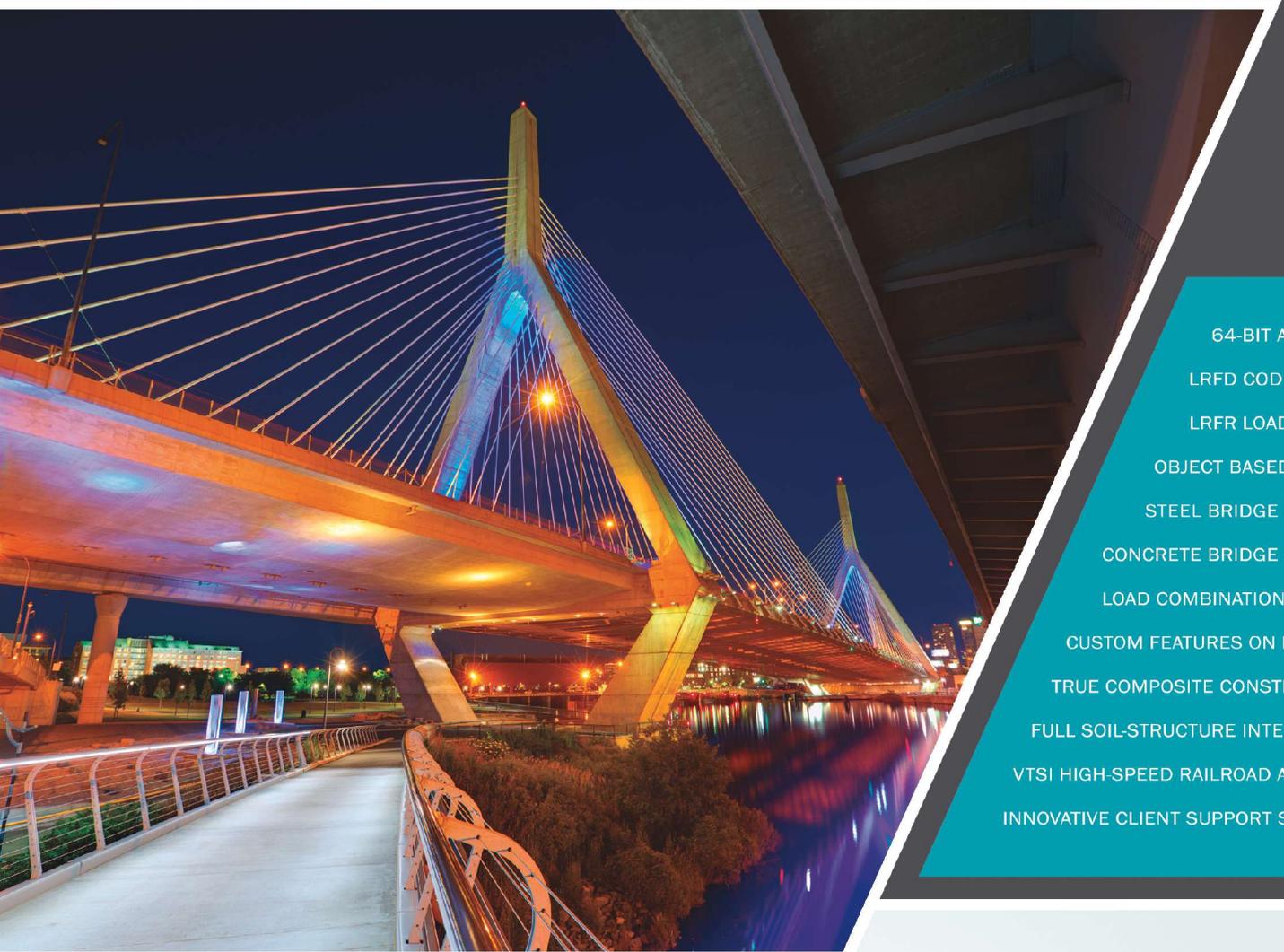
Congratulations to everyone who collaborated on the SR 520—the 2017 ACEC Grand Conceptor Award winner. There's a lot of innovation in this floating concrete bridge.





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