ASPIRE®

THE CONCRETE BRIDGE MAGAZINE

SUMMER 2023

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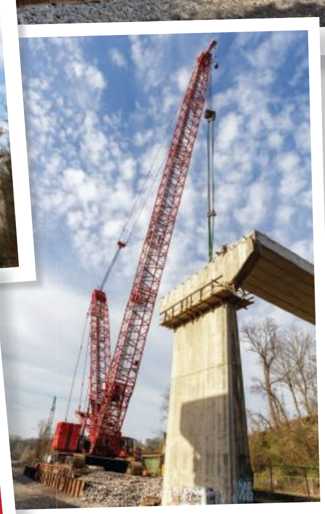
Kraemer Spans a Century of Success

Building technically challenging bridges for more than 100 years



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EDITORIAL

Photo: PCI.

A Call to Action: The Industry Needs Us!

William N. Nickas, *Editor-in-Chief*

In my editorial in the last issue of *ASPIRE*® (Spring 2023), I noted that my daughter's science teacher had wrongly claimed that concrete is not a sustainable material. What struck me about my daughter's story was the way in which her science teacher took direct aim at any high-CO_2-emitting process and product as not being a sustainable construction practice or construction material. The teacher's message was that concrete's carbon footprint relative to the environment is not sustainable for the future. This manner of thinking—prioritizing embodied carbon over everything else, including public safety—is becoming increasingly popular.

In the same editorial, I shared Chris Lechner's outstanding letter to the editor of the *San Antonio Express-News* refuting many of the untruths circulating about concrete and sustainability. That letter struck such a chord with me. Finally, someone pushed back, and did so from a credible and knowledgeable position. I believe his letter exemplifies what we can—and should—say to the critics of our industry. I hoped these examples would jump-start a thought and seed the conversation, all with the goal of motivating everyone in our profession to share the complete story of concrete's sustainability in relation to the full service life of the structure.

As Emily Lorenz pointed out in a Concrete Bridge Stewardship article (*ASPIRE* Fall 2022), sustainability has three pillars—environment, economy, and society—and any full assessment of a project's sustainability must therefore consider the project's impact on all three. She and other sustainability experts are cautioning us to use good science for life-cycle analysis (LCA). However, some practitioners are now trying to reshape LCA studies, by focusing on and prioritizing just one aspect of environmental sustainability: cradle-to-gate embodied carbon. They are losing sight of the impacts that incomplete analyses and uninformed decisions can have on other environmental issues, as well as on the other two equally important pillars, society and economy. We run the risk that decision-makers will lose sight of what an LCA *can't* measure—namely, the full array of social, economic, and environmental costs and benefits that will be associated with any infrastructure project.

For every major infrastructure investment, project, development, and environmental (PD&E) studies document and quantify the potential impacts and benefits, including evaluation of the "no-build" option. Pick up a 30-year-old PD&E study and take a young engineer or student to visit the built project. Try and imagine if the no-build solution had been selected. As the stewards of this nation's bridge construction projects, we need to make sure that stakeholders keep front of mind that bridges are essential for connecting communities and for moving people and goods quickly and efficiently, and that these social and economic benefits can be accomplished in environmentally responsible ways using concrete.

I am particularly concerned that the narrow focus on embodied carbon may come at the expense of public safety. In recent debates within some engineering bodies, it was implied that general civil and structural safety factors are too high and that seismic provisions use excessively long recurrence intervals—these views made my head explode! How can engineers contemplate and, worse yet, justify the notion that saving small amounts of materials to reduce the carbon footprint of projects is worth accepting a higher probability of structural failure and possibly fatalities? This type of absurd thinking could kill thousands—whether directly or by lack of timely response to emergencies—and it could stop construction of resiliency projects such as shore and scour protection, as well as seismic retrofit projects.

We need to address the environmental issues that we face. As engineers, it is our nature to be inquisitive. Although we often use classic and proven

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Kraemer North America built the unique Park Road Bridge in Iowa City, Iowa, which includes a 10-ft-wide multiuse path and alleviates extreme flooding along the Iowa River. Photo: Kraemer North America.

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Postmaster: Send address changes to *ASPIRE*, 8770 W. Bryn Mawr Ave., Suite 1150, Chicago, IL 60631. Standard postage paid at Chicago, IL, and additional mailing offices.

ASPIRE (Vol. 17, No. 3), ISSN 1935-2093, is published quarterly by the Precast/Prestressed Concrete Institute.

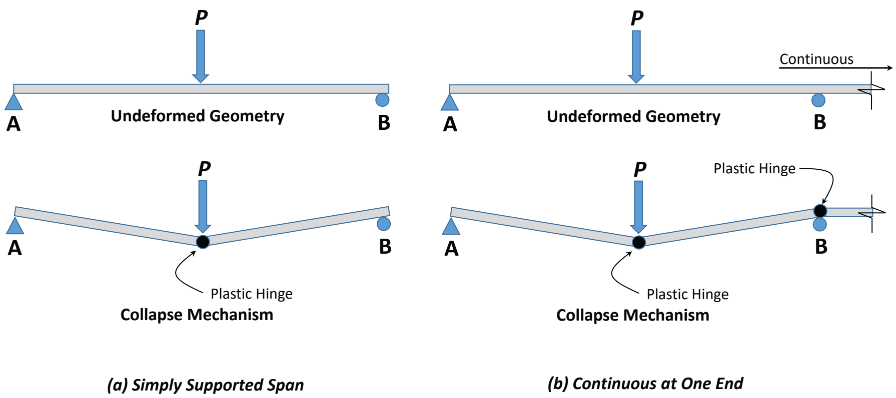
https://doi.org/10.15554/asp17.3

methods to solve today's engineering dilemmas, we also understand our environmental footprint and we pledge to use LCAs appropriately to optimize and reduce the cradle-to-grave impact of infrastructure projects. In fact, we have been incorporating life-cycle cost analysis (LCCA) into plan development for decades and understand these long-term investments. Moving forward, we will continue to methodically identify problems, incorporate rational mathematical explanations, and provide practical solutions that consider the whole puzzle—not just isolated pieces.

We are not averse to new technologies or techniques. Once they are proven, we absolutely embrace them. Because we believe in innovation, our industry invests enormous resources in the research and development of new materials, technologies, techniques, methods, and procedures. For example, load- and resistance-modifier factors, which create uniform levels of safety, are critical concepts that engineers have spent decades improving. Please go back and carefully read Dr. Oguzhan Bayrak's concise articles on structural behavior in the Summer 2020, Winter 2021, and Spring 2021 issues of *ASPIRE*. The engineering concepts and engineering judgment now rooted in design specifications should always uphold our ethical duty to society for safety. The notion that we should revisit the safety margins that are embedded in our structural codes is extremely upsetting to me, as it should be to you.

LCCA, sustainability, and resilience are not new concepts, and yet I feel like we are in a constant battle to defend the tried-and-tested structural theorems of our profession. It is apparent that we are not doing a good enough job telling our robust story. Conversations that dismiss the performance characteristics and measurable successes of our built projects do us a disservice. The beauty of concrete is its sustainability. This is our most resilient story!

Fundamental structural behavior.



To learn more about the topic of structural behavior, see Dr. Oguzhan Bayrak's *ASPIRE* articles at the following links:

https://www.aspirebridge.com/magazine/2020Summer/Prespective-PerspectivesOnStructuralBehaviorAndRedundancy.pdf

https://www.aspirebridge.com/magazine/2020Summer/AASHTO-LRFD-ColumnTiesForNonseismicApplications.pdf

https://www.aspirebridge.com/magazine/2021Winter/Perspective-RedundancyAndDuctility.pdf

https://www.aspirebridge.com/magazine/2021Spring/Perspective-PerspectivesOnStructuralBehaviorAndRedundancy.pdf

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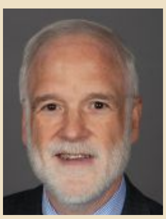

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CONCRETE CALENDAR 2023–2024

The events, dates, and locations listed were accurate at the time of publication. Please check the website of the sponsoring organization.

July 26, 2023
2024 PCI Design Awards
Submission deadline

July 30–August 3, 2023
AASHTO Committee on Materials and Pavements Annual Meeting
Westin San Diego Bayview
San Diego, Calif.

August 17–18, 2023
ASBI Construction Practices for Segmental Concrete Bridges Seminar
Hotel Fontenot
New Orleans, La.

September 5–8, 2023
Western Bridge Engineers' Seminar
Sheraton Phoenix Downtown
Phoenix, Ariz.

September 11–15, 2023
PTI Certification Week
Embassy Suites by Hilton
Scottsdale Resort
Scottsdale, Ariz.

October 1–4, 2023
AREMA Annual Conference with Railway Interchange
Indiana Convention Center
Indianapolis, Ind.

October 3–6, 2023
PTI Committee Days
Ritz-Carlton Cancun
Cancun, Mexico

October 4–8, 2023
PCI Committee Days Conference
JW Marriott Tampa
Tampa, Fla.

October 14–16, 2023
PTI Certification Week
Terracon Consultants
Nashville, Tenn.

October 29–November 2, 2023
ACI Concrete Convention
Boston Convention Center
and Westin Boston Waterfront
Boston, Mass.

November 5–8, 2023
ASBI Annual Convention and Committee Meetings
Westin La Paloma Resort and Spa
Tucson, Ariz.

January 7–11, 2024
Transportation Research Board Annual Meeting
Walter E. Washington Convention Center
Washington, D.C.

January 22–25, 2024
World of Concrete
Las Vegas Convention Center
Las Vegas, Nev.

February 6–9, 2024
PCI Convention at The Precast Show
Hyatt Regency
Denver, Colo.

March 24–28, 2024
ACI Concrete Convention
Hyatt Regency New Orleans
New Orleans, La.

June 16–21, 2024
2024 AASHTO Committee on Bridges and Structures Meeting
Westin Indianapolis
Indianapolis, Ind.

September 23–27, 2024
PCI Committee Days Conference
Renaissance Nashville
Nashville, Tenn.

PCI hiring managing director of quality programs

PCI is seeking to hire a managing director of quality programs to start October 1, 2023. The person who takes on this role is responsible for maintaining all PCI certification programs by ensuring program policies are in accordance with industry standards, ensuring established policies are followed appropriately, and representing programs within the industry.

Among the managing director of quality programs' responsibilities are managing PCI Quality Programs for plant, erector, and personnel certification; managing PCI's International Accreditation Service status; managing the creation and maintenance of quality control manuals; driving specification of PCI's certification program by code-writing bodies and specifying agencies; and serving as staff liaison to various PCI committees.

Applicants must have a bachelor's degree in engineering or construction management and be a licensed engineer and a minimum of 10 years of experience in the concrete or construction industry.

Interested applicants may send a cover letter and resume to Beth Taylor, chief financial and administrative officer, at btaylor@pci.org.

FOCUS

Kraemer Spans a Century of Success

For more than 100 years, Kraemer North America has emphasized safety and quality while building technically challenging bridges

by Monica Schultes

With 112 years of experience in the construction industry, Kraemer North America (KNA) seeks to address owners' challenges while providing opportunities to employees through the company's sustained growth. Projects that require a high level of technical experience, innovative equipment, and in-depth knowledge of the delivery process are of particular interest to the firm.

Like any contractor that has lasted for more than 100 years, KNA has evolved with changing market demands, infrastructure needs, and project funding. Based in Plain, Wis., the company has carefully expanded the business to feature alternative delivery methods, including design-build, construction manager/general contractor (CMGC), and, most recently, progressive design-build (PDB).

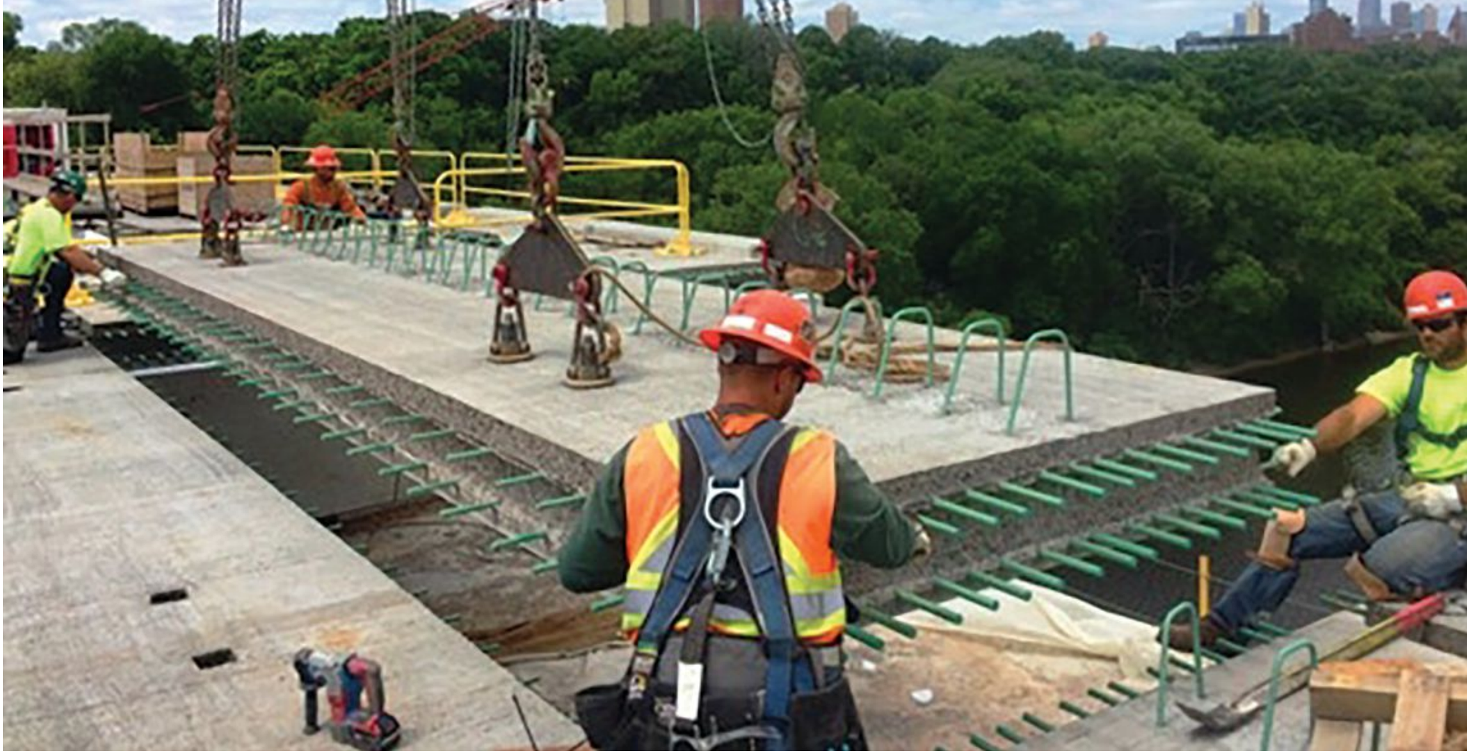
Alternative Delivery Methods

On PDB projects, the design and construction teams are selected based on qualifications at the earliest feasible stage of the project. The increasing popularity of PDB can be attributed to contract flexibility and collaboration. KNA targets projects with technical challenges—those that require innovation and integration of engineered solutions and construction methods. The firm tends to seek projects that are beyond the capabilities of others and require collaboration with owners to address project goals and challenges.

Today, KNA maintains a reputation for safety, quality, and capability as a builder of complex structures. "It is a core part of the Kraemer culture to meet challenges

Construction crews from Kraemer North America used hanging work platforms to access the underside of the West Seattle Bridge to apply carbon-fiber wrapping. Cracks repaired with epoxy injection are visible. Photo: Kraemer North America.

Originally constructed in 1923, the Franklin Avenue reinforced concrete arch bridge over the Mississippi River required substantial rehabilitation. Photo: HNTB.



On the Franklin Avenue Bridge project in Minneapolis, Minn., Kraemer North America collaborated with others on the full removal and replacement of the superstructure beams and a complete replacement of the reinforced concrete bridge deck. Photo: HNTB.

together. We see ourselves as part of the owner's team, not their adversary—we are in this together," says Dave Zanetell, president of KNA. "The success of every project is determined by our people and their commitment to a common goal shared with the owner. At KNA, employees have the opportunity to lead through daily planning and dedication to our core values: integrity, ingenuity, safety, and quality to deliver for our clients."

Although KNA has been building bridges since the 1940s, KNA's bridge division was not officially created until 1957. More recently, the firm's attention to the integration of engineering and construction has helped KNA transition to design-build and other alternative delivery methods. Alternative delivery methods are now approximately half of KNA's business volume. Repeat business is the ultimate validation of their efforts.

Rawson Avenue Bridge

As bridge owners push for faster delivery, construction equipment and technology are helping to make those aspirations a reality. In 2013, KNA used self-propelled modular transporters (SPMTs) during the Rawson Avenue and Interstate 94 (I-94) Bridge replacement near Milwaukee, Wis. Working closely with the Wisconsin Department of Transportation, they demonstrated that accelerated bridge construction (ABC) methods can produce safer projects with less disruption to the traveling public. The new prestressed concrete girder bridge was constructed in two sections along the side of I-94, and both spans were rolled into place within a 12-hour window.

Collaborative Mindset

The scale and complexity of today's bridge projects make collaboration a necessity for a successful outcome. KNA prefers a team-oriented culture and collaborative style to integrate design, temporary works, and execution. For contractors such as KNA, being involved early in the design process is critical to planning project activities while minimizing risks to both owners and the project team. Planning and collaboration are not just valuable to the contractor, but the designer and owner as well. "Boots-on-the-ground input can provide real context to the constructability challenges that may otherwise be overlooked in a bid-build delivery," explains Zanetell.

The setting sun reflects on the Mississippi River and highlights the successful rehabilitation of the Franklin Avenue span above. Photo: HNTB.

"Boots-on-the-ground input can provide real context to the constructability challenges that may otherwise be overlooked in a bid-build delivery."

The new cast-in-place concrete through-arch Park Road Bridge in Iowa City is built to withstand extreme flooding along the Iowa River. Photo: Kraemer North America.

Interstate 280 over the Mississipi River

Feedback from the frontline was vital when meeting with stakeholders to discuss the deck replacement project of Interstate 280 (I-280) between Davenport, Iowa, and Rock Island, Ill. KNA was awarded the bid to remove and replace just under 1 mile of reinforced concrete deck across four lanes on I-280 over the Mississippi River. The deck of the existing bridge, which was built in 1972, was a 9.5-in.-thick reinforced concrete slab on corrugated stay-in-place metal deck forms with a 2-in.-thick concrete overlay. The new 8.5-in.-thick reinforced concrete deck was constructed with traditional wood forms that were removed after construction, allowing for future visual inspections of the underside of the deck.

The deck was replaced in two stages, with the first stage for the westbound lanes constructed between March and October 2021. During the winter shutdown after that stage, KNA collaborated with the Illinois and Iowa Departments of Transportation to revise demolition and access plans for the second stage of construction based on the successes and challenges encountered in the first stage. KNA revised the demolition plan to use hydrodemolition and a linear procedure to ensure that the superstructure was not adversely affected by construction-loading conditions. KNA was then able to preorder materials before the second stage to avoid rework and supply-chain delays. The deck on the eastbound lanes was replaced between March and October 2022.

West Seattle Bridge

When cracks were observed to be growing at an accelerated rate on the West Seattle Bridge across the Duwamish River in Washington state, the structure was closed to traffic for emergency stabilization efforts. KNA's collaborative mindset was once again a project asset. "With 100,000 commuters impacted, the pressure was on to move quickly," recalls Adam Dour, project manager with KNA. The initial repairs occurred

The striking through-arch design of the Park Road Bridge includes a 10-ft-wide multiuse path, seen here from below. Photo: Kraemer North America.

History of Edward Kraemer & Sons

The history of Edward Kraemer & Sons began in 1911 when Kraemer built a house for a friend and established Edward Kraemer & Sons in Plain, Wis. In its early days, the company constructed new homes, barns, and cheese factories. After automobiles became the primary means of transportation in the United States, the Kraemer firm began building short-span concrete bridges in the 1930s and 1940s, and it left commercial building construction altogether in the 1950s.

For decades, Kraemer has found success building roads, bridges, and municipal infrastructure, with technically challenging structures emerging as a core part of the company. Adapting to market demands and infrastructure budgets fueled many of its growth cycles. Alongside the transportation division are rail and marine divisions. The firm currently delivers projects in 14 states, with area offices in Wisconsin, Minnesota, Colorado, and, most recently in Seattle, Wash. Their current work spans from Michigan to Seattle and Minnesota to Texas.

In 2014, Obayashi, a Japan-based global construction firm, invested in a part of Edward Kraemer & Sons. The company transitioned to the name Kraemer North America (KNA), while maintaining its existing leadership and ownership. The partnership with Obayashi has changed very little from an operational standpoint. "Obayashi's technical resources and bonding capacity allow KNA to take on an extra level of complexity and volume, which may have otherwise been a hurdle," explains KNA president Dave Zanetell. "Our approach to projects and our relationships with agencies and owners has been the same throughout. We see this as a mutually beneficial relationship that has provided our team with added depth and technical strength."

Aerial view of the Rawson Avenue Bridge replacement site before the two precast, prestressed concrete girder bridge spans (far right) are moved into position. Photo: Kraemer North America.

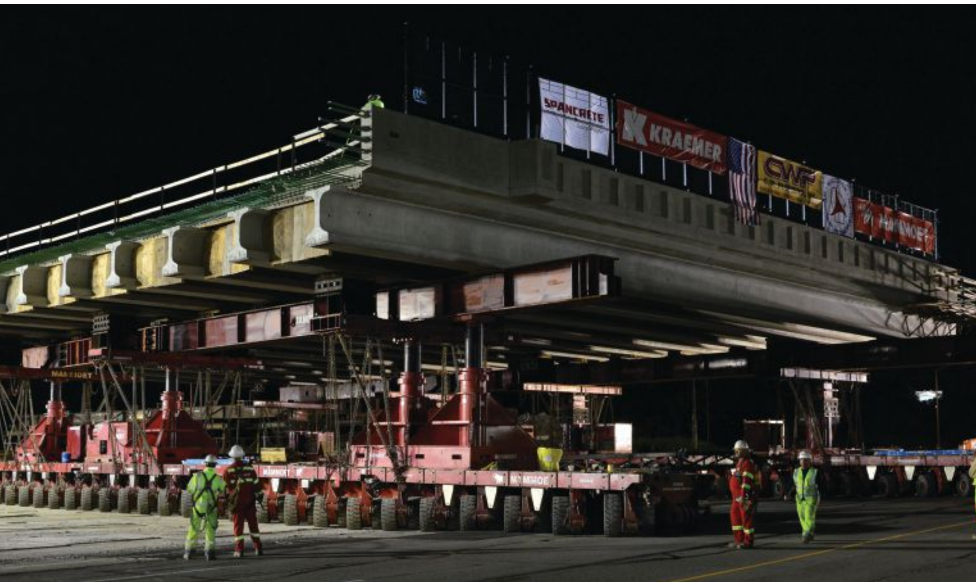
during the early days of the COVID-19 pandemic, and supply chains were fraught with uncertainty.

The work on the West Seattle Bridge involved a two-pronged approach. During the emergency repairs and stabilization of the bridge, the Seattle Department of Transportation (SDOT) evaluated the solutions presented by the project team and opted to rehabilitate the bridge instead of replacing it. KNA contributed ideas and solutions for constructability that helped guide the SDOT decision-making process. Because federal funds were involved, a formalized contracting process was required, and a separate CMGC contract for a second phase was awarded to KNA.

Dour describes some of the challenges the team faced on the jobsite. "It was delicate work to get the new external post-tensioning [PT] anchorages into place. For the new PT, we had to core through 17-ft-thick concrete diaphragms to hit our exit points within tight tolerances—all while in proximity to existing PT ducts. That blind approach was challenging." In addition, KNA had to alleviate a stuck bearing on pier 18 to allow for proper movement in that location. They shifted workforce resources locally to better serve the project and borrowed some personnel from around the company to complete the work.

KNA worked with SDOT and design engineer WSP during the extensive outreach program. "This project is going to raise awareness among other agencies that may have similar structures. The West Seattle Bridge will help address the potential problems that may occur elsewhere," predicts Dour. (For more on the West Seattle Bridge emergency repairs, see the Summer 2022 issue of *ASPIRE®*.)

Using self-propelled modular transporters, Kraemer North America moved two precast, prestressed concrete bridge spans into place in 12 hours on the Rawson Avenue Bridge replacement project. Photo: Kraemer North America.



Franklin Avenue Bridge

Rehabilitation of the Franklin Avenue Bridge over the Mississippi River in Minneapolis, Minn., was another good fit for KNA. This project involved innovations using ABC, owner collaboration through CMGC, and the use of ultra-high-performance concrete (UHPC). To minimize traffic delays and maximize public safety during construction, a 90-day ABC window was established.

Originally constructed in 1923 and previously rehabilitated in 1970, the Franklin Avenue reinforced concrete arch bridge was in a deteriorated state and required substantial rehabilitation. Hennepin County worked with KNA to develop repair solutions—including removal and replacement of pier caps and the reinforced concrete bridge deck—that could be completed within an accelerated schedule.

The project included the removal and replacement of 39 concrete pier caps, installation of 350 new and unique 14-in.-thick precast concrete deck panels, installation of 43 new pier and spandrel cap beams, and placement of 350 yd^3 of UHPC. KNA cast each of the 350 deck panels to ensure that the reinforcement of the adjacent panels fit. (See the Summer 2017 and Winter

2018 issues of *ASPIRE* to learn more about the rehabilitation of the Franklin Avenue Bridge.)

Park Road Bridge

In a joint venture with Peterson Contractors, KNA built the Park Road Bridge in Iowa City, Iowa. This cast-in-place concrete through-arch bridge has a center span length of 250 ft and varies in width from 90 to 110 ft. The signature design is part of the larger Iowa City Gateway Project to mitigate problems from extreme flooding. Completed in 2018, the new bridge spanning the Iowa River is situated 1 ft above the 200-year flood level. It sits on pier foundations supported by 28-ft deep, 8-ft-diameter drilled shafts. The project used 3600 yd^3 of concrete, 1.6 million lb of reinforcing steel, 258,000 lb of post-tensioning strand, 32 precast, prestressed concrete floor beams, and 20 bridge-hanger assemblies. The bottom of the arch is 18 ft from the top of deck.

Rail Transit Projects

For more than half a century, KNA has participated in freight-rail, commuter-rail, and light-rail transit construction projects across the United States. To minimize the costs associated with construction outages, the firm offers clients a comprehensive planning and switch-out process, engineering expertise, experienced personnel, and specialized equipment. KNA's abilities in the rail transit sectior are demonstrated by the many railroad switch-outs under tight time frames that the contractor has completed.

Each railway project involves a distinctive set of challenges. Such was the case for the replacement of a deteriorated 285-ft-long railroad bridge owned by Canadian Pacific Railway over Little Cedar River near Charles City, Iowa. KNA self-performed 100% of the work during the 6-month construction schedule. The project posed several construction challenges. Seasonal weather compressed the schedule and the bridge change-out had to be completed before spring runoff. Another challenge was raising the bridge as much as 17 in. within 6-hour work windows to accommodate an active railway. The bridge comprises six 35-ft spans and two 20-ft spans using 30-in.-deep double-void precast concrete box beams and precast concrete pier caps and abutments. The bridge change-out required seven phases with only brief periods when rail traffic was interrupted.

Set Apart

Proactively addressing potential issues through careful planning has allowed KNA to shine in the construction of complex bridges and alternative delivery methods. Owners reap the benefits as KNA meets demanding schedules, reduces the risks and costs of uncertain outcomes, and collaborates as a team, without sacrificing quality.

In an industry known for its ups and downs, and despite the recent pandemic and market uncertainties, KNA has experienced over a decade of record, profitable growth. With 662 employees, the firm is approximately four times the size it was 10 years ago. Frequently listed by *Engineering News-Record* as being among the top of its field, KNA continues to thoughtfully pursue innovative and challenging projects that align with the firm's core values.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NORTH AMERICA
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West Seattle High Bridge repairs
phase 1 and 2 for the city of Seattle
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Photo by Chun Kwan, SDOT

ASPIRE Readership Survey Results

by Angela Tremblay

The *ASPIRE*® team is enthusiastic about providing interesting and relevant content to inform our readers of new technologies, materials, and methods within the concrete bridge industry, and to help our readers learn and grow in their careers. To that end, we are always looking for ways to improve and remain a valued resource for you, our readers. In Fall 2022, we presented the *ASPIRE* readership survey to solicit feedback, understand the strengths and weaknesses of our publication, and look for fresh ideas within our community. The results are in, and they provide a snapshot of where we stand and great ideas for the future.

Survey Results Summary

We received 455 responses to our 11-question survey. The respondents included a broad spectrum of contractors, owners, consultants, suppliers, students, and professors, with consultants representing more than half of the participant pool (**Fig. 1**).

The value of the magazine's content is reflected by how often readers access and share articles. The following statistics reveal some of our readership data:

- More than 3 out of 4 participants (77%) read most or every issue of *ASPIRE*.
- About 45% of the respondents have been reading *ASPIRE* for more than five years.
- Nearly 20% of the respondents joined our readership in the past year.
- Over 70% of the survey group share articles with peers or colleagues.
- 37% of the survey respondents enjoy reading a hard copy of our magazine, showing that while digital access is increasing, printed materials still have significant value.
- 76% of the respondents rated the value of *ASPIRE* as 7 or greater on a scale of 1 to 10.

Interesting Feedback

The *ASPIRE* team was especially interested to learn what readers enjoy most about the magazine and what new content and improvements they would like to see. **Figures 2** and **3** show the features and content that the survey respondents like best. Project and Concrete Bridge Technology articles are especially popular. Readers also value ideas that they can apply to their projects and clear explanations that further their understanding of the latest advancements in the concrete bridge industry.

In addition to the multiple-choice questions in the survey, there was an opportunity to provide a free-form answer to the question "What does *ASPIRE* not currently offer that you would like to see, or additional topics you think the magazine should cover?" Some recurring suggestions and intriguing ideas from the survey results included:

Figure 1. Survey-respondent representation.

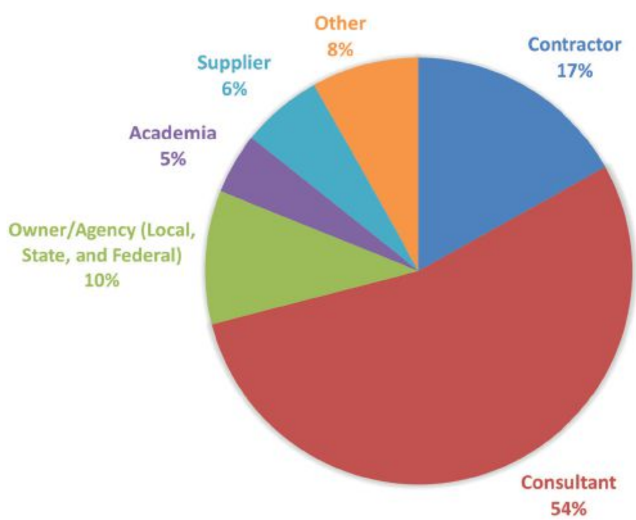
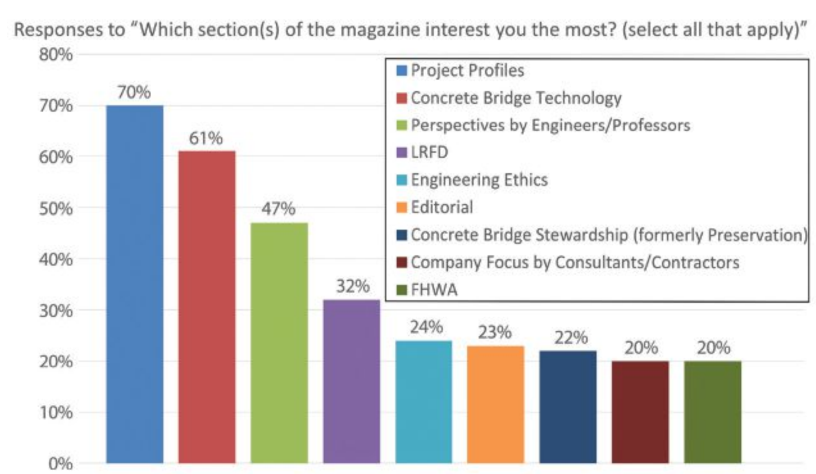


Figure 2. The survey results show which sections of *ASPIRE*® readers find most interesting.



- design resources and calculations,
- lessons learned,
- bridge photos and details,
- concrete material science and sustainability,
- repair and rehabilitation procedures, and
- more Project articles, on projects of all sizes.

What's Next?

Our team has started working on new features and formats to better serve you—our readers—and the broader concrete bridge industry. We welcome your continued feedback through our website (www.aspirebridge.com), where you can also find links to our social media accounts, or via email at info@aspirebridge.org. Thank you again to all the survey respondents for their valuable input.

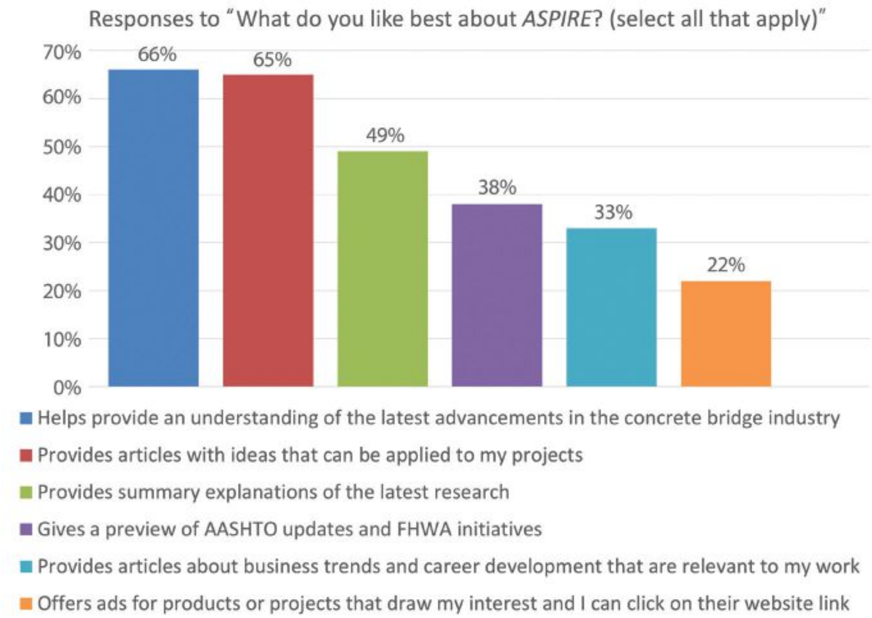


Figure 3. Survey responses provide a snapshot of what readers like best about *ASPIRE*®.

If Not Us, Then Whom? If Not Now, When?

The American Segmental Bridge Institute commits to empowering others for the future

by Jacob Martin, RS&H Inc.

If we all took the time to consider our own personal stories and individual journeys, and asked ourselves, "How did I get where I am today?," our answers would vary because our paths have been different. Whether you are a student, young professional, tradesperson, entrepreneur, industry leader, or a person approaching retirement, you have had unique experiences and opportunities. However, we do not tend to share these experiences and opportunities, both personal and professional, beyond the confines of our close professional or social groups. Though we positively affect those closest to us, we should consider our potential to reach further and affect those beyond our conventional circles. If we do not reach out, who will? And if we do not act now, when will we?

This past year the American Segmental Bridge Institute (ASBI) partnered with organization members to reach out beyond their typical member audience. Furthermore, ASBI sought to invest in the next generation by targeting the education and advancement of engineering students. A volunteer committee, the ASBI Student Program Committee, was formed by a group of energetic individuals: Nyssa Beach (resident engineer, Colorado Department of Transportation), Logan Hall (RS&H Inc.), Jacob Martin (project engineer, RS&H Inc.), Dr. Andrea Schokker (American Concrete Institute), Xue Bing "Jade" Yeap (project engineer, RS&H Inc.), and committee adviser Gregg Freeby (ASBI executive director). This group shared a common goal to not only affect, but also empower future engineers and leaders by developing an initiative centered around progressive learning, scholarship, and mentorship.

During program development, the committee worked diligently to provide students with opportunities to broaden their classroom knowledge and connect with leaders in the transportation/concrete segmental bridge industry. The program involved a student competition as well as invitations to attend and receive mentorship at the 34th Annual ASBI convention in Austin, Texas. To participate in the competition, students were asked to respond to a problem statement on the sustainability of concrete segmental bridges by submitting a video presentation. To help them best respond to the prompt, students were directed to various resources, such as ASBI and Texas Department of Transportation publications, and encouraged to conduct additional research to learn more about concrete segmental bridges, sustainability, and potential uses of new technologies in concrete segmental bridge construction. The submitted video presentations were evaluated, and the top presenters were chosen to attend the ASBI convention, make a live presentation during the convention, and compete for a scholarship. Students who were not selected to compete at the annual

Presentation of awards to the winners of the 2022 American Segmental Bridge Institute Student Competition. Back row from left: Scholarship sponsor representatives Jacob Martin (RS&H), Tim Barry (RS&H), Craig Finley (COWI), Tom Stelmack (Parsons), Carter Masterson (Malcolm International), Ken Price (WSP). Front row from left: Award winners Thomas Costello and Nuzhat Humayun Kabir. Photo: Goen South, The Event Company.

A student competition information packet was distributed to universities to provide students with the guidelines for the 2022 American Segmental Bridge Institute Student Competition. Figure: ASBI Student Program Committee.

conference were still encouraged to attend.

On the first day of the conference, the ASBI Student Program Committee facilitated a student/sponsor/mentor meet-and-greet to further connect students to leaders in the transportation/concrete segmental bridge industry. All students who attended the conference had the opportunity to meet leaders from sponsoring companies and were paired with program sponsors who would mentor them throughout the conference. Mentors were encouraged to introduce the students to colleagues, guide them through the convention, and assist them with networking. Additionally, student participants were able to share their résumés with the program sponsors.

The students who had been selected to compete for scholarships presented during the conference in front of a live audience of transportation industry professionals. Each presentation was followed by a question-and-answer session led by industry experts and program sponsors. ASBI had the distinct pleasure of awarding scholarships to Thomas "TJ" Costello, a graduate student from the University of Oklahoma, and Nuzhat Humayun Kabir, a PhD student from Texas A&M University, for their outstanding presentations. After competing, Costello said that having the opportunity to "present to a room full of so much knowledge was a huge honor," and Kabir expressed gratitude that ASBI was "providing students a platform to reach out to industry professionals."

The goal of our committee is to continue to provide students with unique experiences and opportunities to connect with those in the transportation industry. It is also our hope that the effect we are having now will empower future engineers and leaders to positively affect others. We encourage everyone to reach beyond their immediate area of influence, knowing that they too can make a difference.

As a committee we considered our own personal stories. We considered not only fostered relationships but also acts of kindness from strangers. We recall myriad opportunities provided through learning/education, scholarship, and mentorship. Knowing the influence others have had on us renews our commitment to others. For this reason, my fellow committee members and I, along with ASBI, invite you to empower others to influence our future. Because if not us, then whom? And if not now, when?

Jacob Martin is a project engineer with RS&H Inc. He has consulted on complex bridge projects across the United States, and he served as chair of the 2022 ASBI Student Program and Competition.

AUTHOR'S NOTE

The ASBI Student Program and Competition would not have been made possible without the tremendous support of our sponsors: COWI, Malcolm International, Parsons, RS&H Inc., and WSP.

PROJECT

From Collapse to Commute: Concrete Builds a New Fern Hollow Bridge in 11 Months

by Jason Fuller and Kevin O'Connor, HDR Inc.

Carrying 20,000 vehicles per day on Forbes Avenue in Pittsburgh, Pa., the Fern Hollow Bridge is a critical commuter route through the region and serves as a main detour for Interstate 376. The collapse of the steel bridge in the early morning of January 28, 2022, drew national attention and resulted in extensive local traffic congestion and user delays.

Replacement of the bridge quickly became a priority. Emergency declarations from the state and city cleared the way for urgent action at all levels of government, and a design-build team was selected to replace the important bridge. The team's notice to proceed with the design was issued on February 3, 2022, just six days after the collapse. The City of Pittsburgh delegated the project management of the removal, design, and reconstruction of the bridge to the Pennsylvania Department of Transportation (PennDOT) District 11-0 under a reimbursement agreement. Through collaboration with the Federal Highway

Site preparation work for the west approach to the new Fern Hollow Bridge in Pittsburgh, Pa., on the morning of June 1, 2022. Photo: HDR Inc.

profile

FERN HOLLOW BRIDGE / PITTSBURGH, PENNSYLVANIA

BRIDGE DESIGN ENGINEER: HDR Inc., Pittsburgh, Pa.

OTHER CONSULTANTS: Construction inspection: SAI Consulting Engineers Inc. with JMT & CCS Inc., Pittsburgh, Pa.; construction management: Michael Baker International with CCS Inc., Pittsburgh, Pa.; survey and right-of-way: Monaloh Basin Engineers Inc., Pittsburgh, Pa.; lighting: Santangelo & Lindsay Inc., New Brighton, Pa.; cultural resources and utility coordination: Markosky Engineering Group Inc., Ligonier, Pa.; landscape architecture: Klavon Design Associates Inc., Pittsburgh, Pa.

PRIME CONTRACTOR: Swank Construction Company LLC, New Kensington, Pa.

CONCRETE SUPPLIER: Castle Builders Supply and Trucking LLC, New Castle, Pa.

PRECASTER: PennStress, Roaring Springs, Pa.—a PCI-certified producer

OTHER MATERIAL SUPPLIERS: Column and cap forms: EFCO, Des Moines, Iowa; formliners: Fitzgerald Form Liner, Santa Ana, Calif.; concrete pumping: Howard Concrete Pumping Co. Inc., Canonsburg, Pa.; material chain management for prestressed concrete beams: Weatherspoon & Williams LLC, Houston, Pa.; midspan diaphragms: Shane Felter Industries, Uniontown, Pa.; reinforcing bars: Titusville Fabricators, Franklin, Pa.

Cranes move the 200-kip, 154-ft-long prestressed concrete bulb-tee beams into position on the new Fern Hollow Bridge in late July 2022. Photo: Swank Construction Co.

Administration (FHWA), $25.3 million was allocated toward this reconstruction project thanks to the recently passed Bipartisan Infrastructure Law.

Working alongside PennDOT, FHWA, and Pittsburgh's Department of Mobility and Infrastructure, the design-build team streamlined project delivery in several ways to meet the aggressive construction timeline. The partners worked as a team to transform a tragic incident into a source of community pride.

February 2022: Project Begins

The first weeks of February 2022 were a flurry of activity. By February 17, all steel and concrete from the collapsed bridge had been removed. Meanwhile, as kickoff meetings were held and major design decisions made, work quickly moved forward on designing the replacement structure.

The team moved urgently to establish items such as the design criteria, typical cross section, substructure, span arrangement, and superstructure. The design team quickly identified the historic Frick Park Gatehouse in the southwestern quadrant and a private street on the eastern bridge approach as key constraints. Given these existing features, and the desire to remain within the City of Pittsburgh's existing legal right-of-way, no changes could be made to the existing alignment. With this knowledge, the team decided to match the 64-ft out-to-out width of the previous structure.

During these early conversations, the Pittsburgh Department of Mobility and Infrastructure expressed a desire to maximize multimodal access across the structure, given the park setting and nearby trail facilities. Therefore, the bridge width was reallocated to increase multimodal space by roughly 50% through the addition of a shared-use path.

That led to a proposed bridge with a typical cross section consisting of the following:

- Four 10-ft-wide travel lanes
- 2-ft-wide outside shoulders
- A 5-ft-wide raised sidewalk on the northern side
- A 10-ft 5-in.-wide shared-use path on the southern side (separated from traffic using a PennDOT PA bridge barrier)
- A curb-to-curb width of 44 ft
- An out-to-out width of 64 ft

CITY OF PITTSBURGH / PENNSYLVANIA DEPARTMENT OF TRANSPORTATION DISTRICT 11-0, OWNERS

BRIDGE DESCRIPTION: Three-span, 460-ft-long, prestressed concrete beam bridge made continuous for live load, with a 5-ft-wide sidewalk, a 10-ft 5-in.-wide shared-use path, and a typical cross section that maintains an out-to-out width of 64 ft

STRUCTURAL COMPONENTS: Twenty-one 95.5-in.-deep, 153-ft 8-in.-long PA bulb-tee beams, weighing over 200 kips each; 9-in.-thick total cast-in-place concrete deck (including 1-in.-thick polyester polymer concrete overlay); PA bridge barrier and pedestrian rail with open line of sight for views of park below; cast-in-place concrete pier caps, columns, and drilled shafts; integral abutments founded on drilled steel piles

BRIDGE CONSTRUCTION COST: Approximately $12 million ($408/ft^2) (all bridge-related items, but only bridge)

AWARDS: American Society of Civil Engineers Pittsburgh: 2022 Civil Engineering Achievement Award; Pennsylvania Society of Professional Engineers, Pittsburgh Chapter: Outstanding Engineering Achievement Award; Engineers' Society of Western Pennsylvania: 2022 Emergency Replacement Project of the Year; March of Dimes Pittsburgh: 2022 Transportation Project of the Year; Association for Bridge Construction and Design Pittsburgh Chapter: 2022 Award for Outstanding Multi-Span Bridge; International Bridge Conference 2023: Award of Merit for Emergency Response

Several of the nearly 8-ft-deep prestressed concrete PA bulb-tee beams were erected by early August 2022. The historic Frick Park Gatehouse is barely visible at the far left corner of the bridge. Photo: HDR Inc.

The nearly 154-ft-long prestressed concrete beams were delivered in early August 2022. In this photo, the delivery truck is staged and waiting to be driven backward for a mile to the west side of the project site. Photo: HDR Inc.

The project team carefully considered the superstructure type and final span arrangement for the proposed structure. Multiple options were evaluated, including a prestressed concrete structure, a steel structure, and a steel or concrete arch structure. The team had to avoid adverse consequences for both Tranquil Trail and the Fern Hollow Creek below the structure, while also anticipating how different span arrangements would affect beam delivery and erection.

The design-build process allowed the agencies and designer to develop reasonable options, which the contractor assessed based on which material types were most readily available and cost effective. Ultimately, after weighing the fabrication lead times, delivery routes, aesthetics, effects on the park below the bridge, beam delivery, beam erection, and estimated costs, the team chose a prestressed concrete beam bridge made continuous for live load as the optimum solution. Design then moved forward with the following configuration:

- Three-span composite prestressed concrete structure
- Total length of 460 ft
- A total of 21 PA bulb-tee beams, 7 beams per span spaced at 9 ft 5 in. on center, each measuring about 8 × 154 ft and weighing more than 200 kips
- Two-column piers founded on 8.5-ft-diameter drilled shafts
- Integral abutments located behind the original masonry abutments, which were to be retained
- Height of 100 ft from the bridge deck to the recreational path below

Delivery of the prestressed concrete beams generated considerable attention from local residents and the media. Photo: HDR Inc.

The team knew that it would be challenging to maneuver the large concrete beams through urban streets and neighborhoods to the site for erection. But prestressed concrete beams were the earliest available superstructure material, and their use increased the possibility of reopening the bridge to traffic within a single construction season. Early coordination among the contractor and the representatives from the precast concrete industry was critical to making this structure choice realistic. Working together, they determined that the beams could be delivered and there was a reasonable way to erect them.

The team also discussed at length the appropriate substructure types. Because of the site's proximity to the Frick Park Gatehouse, pile foundations could not be driven. The team sought to avoid fully replacing the existing abutments because that would require extensive shoring and increase the project cost. Instead, the bridge design proceeded with integral abutments and two

East-southeast view of concrete deck work continuing on the east side (span 3) of the new Fern Hollow Bridge in Pittsburgh, Pa., in October 2022. Photo: Swank Construction Co.

8.5-ft-diameter drilled caissons per pier for piers 1 and 2.

Another strategy that accelerated the project was the formulation of a baseline schedule that merged design and construction activities to identify the project's critical path and determine if full- or partial-design submissions were appropriate to meet the aggressive construction schedule.

March and April: Design Hits Fast Forward

Design activities dominated the next few months. Design commenced from the top down (as is typical for bridges) and from the bottom up, with the designer using experience with local geology and geotechnical data recently developed for a nearby bridge replacement project.

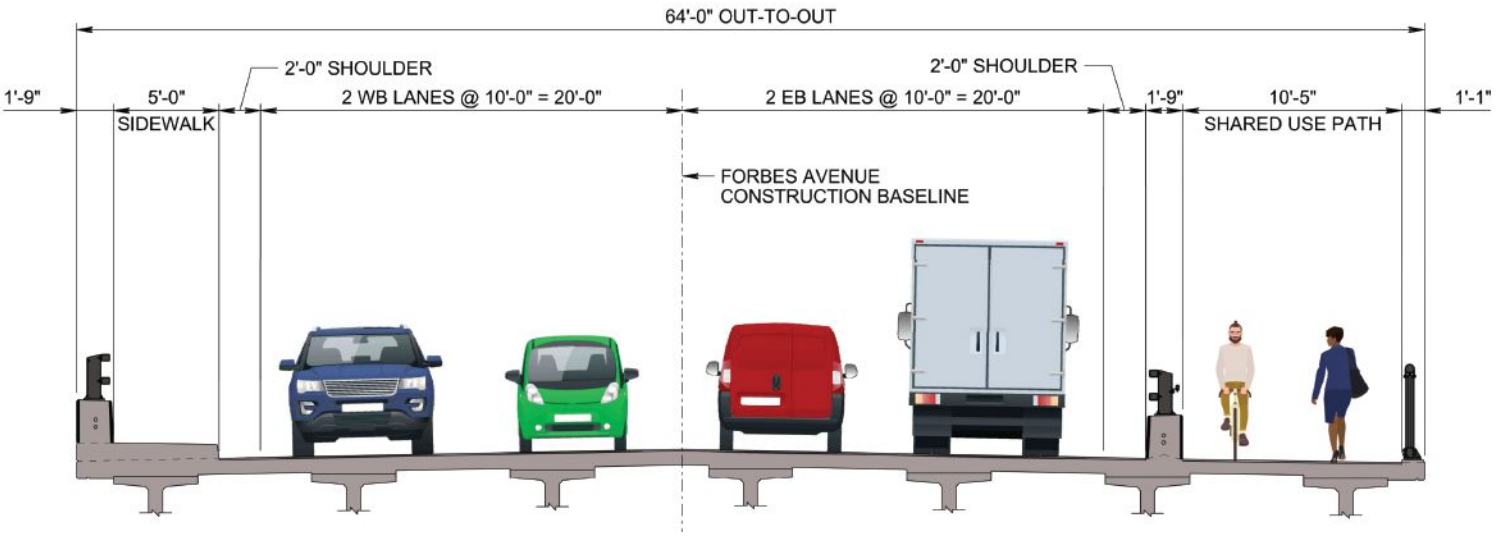
The overall design work was divided into packages, with components likely to have a longer lead time undertaken first. Design-build delivery required the team to design with procurement, fabrication, and construction in mind so that the contractor could start as soon as the winter weather cleared. The first of these design packages, delivered in March, included beams and bearings because they have some of the longest lead times for procurement. Then came the foundations because they would be the first items constructed. The partial submissions for pier and abutment design were submitted in April and accepted in May—a critical step that allowed the contractor to break ground on the new bridge and begin construction.

The partial beam and bearing design packages allowed the team to accelerate procurement of the beams. Using partial submissions and approvals instead of waiting for complete plan sets shaved months off the project schedule. This strategy was made possible because the team had trust in the quality of the designs, the timeliness of the reviewers, and the experience of the fabricator and their ability to produce the shop drawings. Throughout March and April, the general layout of shop drawings began, then details were implemented once partial packages were approved.

By the end of April, the bulk of the bridge design activities had been completed, about three months after the unexpected collapse of the previous bridge. With some exceptions, structure design plans were complete, shop drawings were underway, and materials were being fabricated.

Less than 11 months after the collapse, the replacement bridge was opened to traffic. Photo: HDR Inc.

All precast concrete beams were in place on the new bridge by late August 2022. Photo: HDR Inc.



Typical cross section of the new bridge. Figure: Pennsylvania Department of Transportation.

May through November: Construction

While design was progressing, the contractor and the project's suppliers worked to prepare for construction to begin in earnest in May 2022. Material procurement progressed throughout the colder months so that construction crews could hit the ground running in May. Construction began with the drilling of the pier caissons in Fern Hollow. With the approval of the beam design package and shop drawings completed and accepted in April, fabrication of the 21 prestressed concrete bulb tees (33-in.-wide and 95.5-in.-deep PA bulb tees) began in May and ended in early June. The beams had a design concrete compressive strength at transfer of 8.5 ksi and a 28-day strength of 10 ksi. Each beam used eighty 0.6-in.-diameter Grade 270 low-relaxation strands. By late July, the site was almost ready for beam erection.

Delivery of the massive beams attracted considerable attention from neighborhood residents and the media. For the beams on the west side of the project, the delivery vehicle had to be driven backward for a mile by an operator at the rear of the vehicle. For much of the way, local residents lined the route and applauded the arrival of the beams.

Big beams require large cranes for erection, and in this case, two large crawler cranes were used to set the beams. For the initial unloading pick, a Manitowoc MLC-650 with a variable counterweight positioning system was used. This type of crane was required because each beam weighed over 200 kips and it was necessary to reach out to the center of the end spans. The massive crane (including counterweights) was delivered to the site on 45 separate trucks, and thirty-eight 10-ton counterweights were required for the lifts at Fern Hollow. Operators used a smaller crane (MLC-300), which was driven down the access road to a crane pad below the bridge after full assembly, to help move beams to the center spans. For span 2, operators of the larger crane temporarily placed the beams on span 1 and then used both cranes for a tandem pick to move the beams from span 1 to their final location in span 2.

Crews worked on deck forming and reinforcing bar installation in August, and started deck placement in late September. The 9-in.-thick deck is composed of an 8-in. composite concrete cast-in-place deck with a 1-in. polyester-polymer concrete overlay. All deck reinforcement is Grade 60 epoxy-coated reinforcing steel. Crews erected beams as simple spans and placed continuity diaphragms at the piers with a continuously reinforced concrete deck over the entire length of the bridge. By October, deck construction was complete and tie-in work began.

December: Open to Traffic

Less than 11 months after the collapse, the ribbon-cutting ceremony for the new bridge was held on December 21, 2022, and traffic started flowing the next day. Work continues on some components, including a bridge deck overlay, lighting installation, and the midblock pedestrian crossing on the western roadway approach; all of these are scheduled to be completed in summer 2023. At the bridge opening, both politicians and project leaders praised the teamwork and dedication that made the rapid completion of the new bridge possible.

"I was here on January 28 to survey the damage from the collapse, and today, less than a year later, I stand before a bridge that is nearly ready to reopen to traffic," said Pennsylvania governor Tom Wolf. "This is the power of government working for the people in Pennsylvania. It's an honor to be here to celebrate this incredible milestone for Pittsburgh."

Jason Fuller is a vice president and senior project manager and Kevin O'Connor is a senior project manager with HDR Inc. in Pittsburgh, Pa.

EDITOR'S NOTE

The new Fern Hollow Bridge is featured in a Project Spotlight article, "Collapsed Pittsburgh Bridge Replaced in Less than a Year," in the May–June 2023 issue of PCI Journal. *That article describes the exceptional collaborative efforts of the stakeholders to achieve the aggressive schedule and deliver the new bridge in less than one year. It also features additional photos of the challenging beam delivery and erection processes. https://doi.org/10.15554/pcij68.3-06.*

Cutler Road Bridge over the Looking Glass River

Record-setting beams provide the solution for spanning the Looking Glass River in Ionia County, Michigan

by Jordan Pelphrey, Neha Yadav, and Haley Newhouse, Williams & Works Inc.

Located approximately 2 miles east of the city of Portland, Mich., the new Cutler Road Bridge crosses the Looking Glass River and connects the townships of Danby and Portland in Ionia County. The road serves as a main access route for many residents within the community, with school buses and emergency vehicles crossing the bridge daily.

The previous bridge, which was built in 1980, was 167 ft long and 31.5 ft wide. It was considered non-historic, consisting of six timber spans with a nail-laminated timber deck structure and a bituminous asphalt wearing surface as well as timber piles, piers, and abutments. When the structure was posted for a load restriction due to deterioration of multiple components, the Ionia County Road Commission (now the Ionia County Road Department) tasked the bridge design consultant with design and construction engineering services for the replacement bridge.

Project Description

The structure type was to be either a two-span prestressed concrete spread box-beam structure or a two-span steel I-beam structure, with equal span lengths of 85 ft, a single pier located in the Looking Glass River, and five beam lines. During the permitting process, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) required that no piers be located in the water because the river contains a species of mussels listed as threatened by the state. EGLE recommended using a bridge with shorter tail spans and a longer center span to avoid the water. Other measures to protect the species included a native freshwater mussel survey, relocation of 405 mussels, and continued mussel monitoring.

The truck backs up the first 126-ton beam to the crane on the west end of the bridge. The unique erection process uses two 550-ton hydraulic cranes—one on each end of the bridge— and a custom beam launcher or "carriage" unit. All Photos: Williams & Works Inc.

Rather than designing a bridge with multiple spans, the design team

profile

CUTLER ROAD BRIDGE OVER LOOKING GLASS RIVER / IONIA COUNTY, MICHIGAN

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: Williams & Works Inc., Grand Rapids, Mich.

OTHER CONSULTANTS: Ionia County's engineering representative: Prein & Newhof, Grand Rapids, Mich.; geotechnical engineer, materials testing subcontractor, and prestressed concrete beam third-party inspector: Soils & Structures Inc., Grand Haven, Mich.; steel fabrication third-party inspector: Integrated Inspection LLC, Grand Haven, Mich.; asbestos testing and native mussel survey, relocation, and monitoring: ASTI Environmental, Brighton, Mich.

PRIME CONTRACTOR: Davis Construction Inc., Lansing, Mich.

CONCRETE SUPPLIER: Consumers Concrete Corporation, Kalamazoo, Mich.

PRECASTER: Prestress Services Industries LLC, Decatur, Ind.—a PCI-certified producer

The first beam travels on the beam launcher. Once the beam is within reach of the crane on the opposite (east) side, both cranes set

selected a single-span option. They chose prestressed concrete because it was found to be the lowest-cost option for materials, and they proceeded with a design solution that eliminated six beams and a pier in the water.

The new bridge is 175 ft 0 in. long and 35 ft 4 in. wide, and has a 25-degree skew. The superstructure consists of four 84-in.-deep bulb-tee beams spaced at 9 ft 4 in. with a 9-in.-thick cast-in-place (CIP) concrete deck using epoxy-coated reinforcing steel. The span and beam lengths are 171 ft 0 in. and 173 ft 0 in., respectively. Other bridge components include steel H-piles, CIP concrete footings and abutments, lightweight expanded polystyrene fill blocks (to reduce pile loading), steel sheet piling, and four-tube steel railing. To accommodate the depth of the superstructure, which was greater than that of the existing six-span timber bridge, the grade was raised approximately 6 ft.

The design of the structure was based on 1.2 times the HL-93 loading specified in the ninth edition of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*,[1] except that the design tandem portion of the HL-93 load definition was replaced by a single 60-kip axle load before application of the 1.2 factor. This resulted in a load designation of HL-93 MOD, which is typical of Michigan Department of Transportation (MDOT) bridge designs. All work on the project is according to the project special provisions and MDOT's *2020 Standard Specifications for Construction*.[2]

According to MDOT, the Cutler Road Bridge is the longest single-span prestressed concrete bridge over water

The 7-ft-deep prestressed concrete beams are among the largest in use in Michigan.

IONIA COUNTY ROAD DEPARTMENT, OWNER

OTHER MATERIAL SUPPLIERS: Crane subcontractor: Erickson's, Grand Rapids, Mich.; steel rail and diaphragm fabricator: Cardinal Fabricating Inc., Williamston, Mich.

BRIDGE DESCRIPTION: Single-span 175-ft-long (171-ft span length), 32-ft-wide clear roadway (35-ft 4-in. out-to-out width) bridge with a two-lane skewed deck, precast, prestressed concrete bulb-tee beams, and 20-ft-long concrete approach slabs

STRUCTURAL COMPONENTS: 173-ft-long, 7-ft-deep, precast concrete bulb-tee beams with a 4-ft 1-in.-wide top flange, 9-in.-thick cast-in-place reinforced concrete deck, cast-in-place reinforced concrete abutments, wing walls, approach slabs, and sleeper slabs

BRIDGE CONSTRUCTION COST: $4.43 million

Placing the deck on the Cutler Road Bridge.

Aerial view of all four beams in place. The single-span solution eliminated six beams and a pier in the water.

in Michigan and the second-longest span overall in the state (the longest span is 171 ft 6 in.). Each beam weighs 126 tons and includes 84 permanent 0.6-in.-diameter pretensioning strands, with six of the strands located in the top flange to improve lateral stability and control stresses during lifting, transportation, and installation. The concrete compressive design strengths are 7200 psi at transfer and 8200 psi at 28 days. The beam manufacturer reported average as-built concrete strengths of approximately 8800 psi at transfer and 13,000 psi at 28 days.

Prestressed concrete spans longer than 160 ft are uncommon in Michigan, so much so that the beam's cross-sectional depth of 84 in. is not listed in MDOT's Bridge Design Guides[3] or Bridge Design Manual,[4] which report a maximum depth of 72 in. The beam manufacturer was consulted early in the design phase to ensure that a beam this deep and long could be fabricated and transported to the bridge location.

Because their history of projects in the state using prestressed concrete beams over 160 ft was limited, the design team added a special provision that required the precaster to perform an independent beam lateral stability and stress analysis conforming to PCI's *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*,[5] and the AASHTO LRFD specifications to ensure that the beams would be laterally stable during lifting, transportation, and installation. Under this special provision, a licensed professional engineer had to sign the analyis and the precaster was required to monitor and record beam camber and sweep at various time intervals.

Design

In addition to restrictions related to the protection of the threatened mussels species, several other restrictions came from the permitting process. No in-water work was to take place between March 1 and June 30, when warm-water fish species migrate and spawn. The project is in an area that provides habitat for the federally threatened eastern massasauga rattlesnake, so the use of certain types of materials for soil erosion and sediment control was restricted. It is also within the range of the northern long-eared bat, which is federally listed as an endangered species, as well as the Indiana bat; therefore, tree removal was not allowed between April 1 and September 30.

The project's design schedule was slowed by multiple challenges. First, after the COVID-19 pandemic started, collaboration between staff and agencies on design work was impaired for several months as people adapted to working from home. Also, while the team was completing the design, MDOT updated its *2012 Standard Specifications for Construction*. All design work then had to conform to the new 2020 edition of the specifications, so a significant number of revisions were required. The schedule was also affected as staffing changes across the entire team led to schedule postponements.

Construction

These design schedule delays resulted in the project not going out for bid until February 2022, a full year later than originally planned. MDOT awarded the construction contract to the contractor on March 29. As previously mentioned, tree removal had to be completed before April 1 to avoid potential disturbance of bats. More than 60 trees were removed within two-and-a-half days. Once tree removal was completed, the contractor shifted focus to bridge removal. At that point, the team found that a previously undiscovered utility, hidden under the railing, extended across the bridge. Relocating the utility delayed the project an additional six weeks, with construction restarting on May 10.

The four prestressed concrete beams were erected on September 20 and 21, 2022, with two beams set each day. Transportation from the prestressing plant in Indiana to the Michigan–Indiana border required a police escort. The precaster carefully planned the route by selecting navigable intersections and avoiding active construction. After a beam-transporting truck exited the freeway, it was backed down Cutler Road to the bridge site, approximately 1.7 miles from the exit.

Two 550-ton hydraulic cranes were placed on either side of the bridge. The contractor installed a temporary beam launcher, consisting of two steel wide flange sections and several steel cross members, to assist in erecting the beams. The ends of the launcher were placed on the east and west abutments. The launcher included three temporary supporting H-pile bents located at the quarter points.

The Cutler Road Bridge was opened to traffic in December 2022.

Beam erection began by the truck driver backing the truck up to the crane on the west side of the bridge; then, the crane lifted one end of the beam. The truck driver continued to back up the truck while the crane positioned the beam on the launcher's traveling carriage unit. The beam was unhooked from the crane after it was secured to the carriage unit. The truck driver continued to back up the truck while the beam traveled on the carriage unit along the launcher. Once the beam was backed up far enough, the crane was used to pick it from the truck. Meanwhile, on the east side of the bridge, the contractor connected a steel cable to the carriage unit and began pulling the beam toward the abutment while the crane on the west end guided it. Once the beam was within reach of the east crane, the east crane picked the beam from the carriage unit, and both cranes were used to set the beam in place.

After beam erection, the contractor completed construction on the remaining elements of the bridge, including placing the concrete deck, paving, and installing guiderail. The bridge was opened to traffic on December 22, 2022.

Through collaboration, the design team and the contractor successfully surmounted environmental restrictions, beam delivery and erection challenges, and a pandemic to achieve a successful project.

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Jordan Pelphrey is a senior structural engineer and project manager, Neha Yadav is a structural project engineer, and Haley Newhouse is a resident project representative with Williams & Works Inc. in Grand Rapids, Mich.

PROJECT

Harbor River Bridge Replacement

by Lynda Monroe, Infrastructure Consulting & Engineering PLLC

As the only means for vehicular transportation from the mainland to Harbor Island, Hunting Island, and Fripp Island, the Harbor River Bridge (U.S. Route 21 over Harbor River) in Beaufort County, S.C., is an important transportation link. The original swing-span bridge over a tidal waterway and navigable channel was in poor condition and required replacement. The design-build project to replace the original structure was awarded in August 2017. The new structure, which opened to traffic in April 2021, is a high-level, 3340-ft-long fixed-span bridge that provides uninterrupted access for shrimping and sailing vessels along the river below, as well as safety improvements for motorists crossing the bridge.

The complex bridge is designed to withstand hurricane-force winds, seismic events, vessel collisions, and significant long-term scour. Preserving the pristine environmental setting and satisfying environmental permit constraints were other design concerns.

The size of the replacement bridge makes it a focal point for the local community and completely transforms the landscape of the surrounding area. The structure spans a significant distance over environmentally sensitive salt marshes and a tidal river from St. Helena Island to Harbor Island. The layout of the bridge was established to satisfy the required vertical clearance over the 90-ft-wide navigational channel (65-ft minimum vertical clearance from the mean higher high-tide elevation to the low chord), and to meet the existing roadway using a maximum grade of 4%. The total bridge length is 3340 ft, and the maximum height is approximately 120 ft from the top of the deck to the bottom of the river at its highest point.

The new 3340-ft-long Harbor River Bridge carries U.S. Route 21 over environmentally sensitive habitat. Photo: Kaze Aerial Production.

profile

HARBOR RIVER BRIDGE REPLACEMENT / BEAUFORT COUNTY, SOUTH CAROLINA

BRIDGE DESIGN ENGINEER: Infrastructure Consulting & Engineering PLLC, West Columbia, S.C.

OTHER CONSULTANTS: Geotechnical engineer of record: GeoEngineer Inc., Charleston, S.C.; bridge hydraulic design: Taylor Engineering Inc., Jacksonville, Fla.; geotechnical investigation: Terracon Consultants Inc., St. Louis, Mo., Mid-Atlantic Drilling Inc., Wilmington, N.C., and Catlin Engineers, and Scientists, Charleston, S.C.; materials testing: Insight Group LLC, Charleston, S.C.

PRIME CONTRACTOR: United Infrastructure Group Inc., Great Falls, S.C.

CONCRETE SUPPLIER: Low Country Concrete Inc., Beaufort, S.C.

PRECASTER: Prestressed concrete piles and beams: Standard Concrete Products, Savannah, Ga.—a PCI-certified producer

OTHER MATERIAL SUPPLIERS: Reinforcing bar: Harris Rebar, Catawba, S.C.; compression seal expansion joints, anchor bolts, tie rods: Georgetown Mill Supplies, Georgetown, S.C.; laminated bearing pads: New South Construction Supply, Charlotte, N.C.

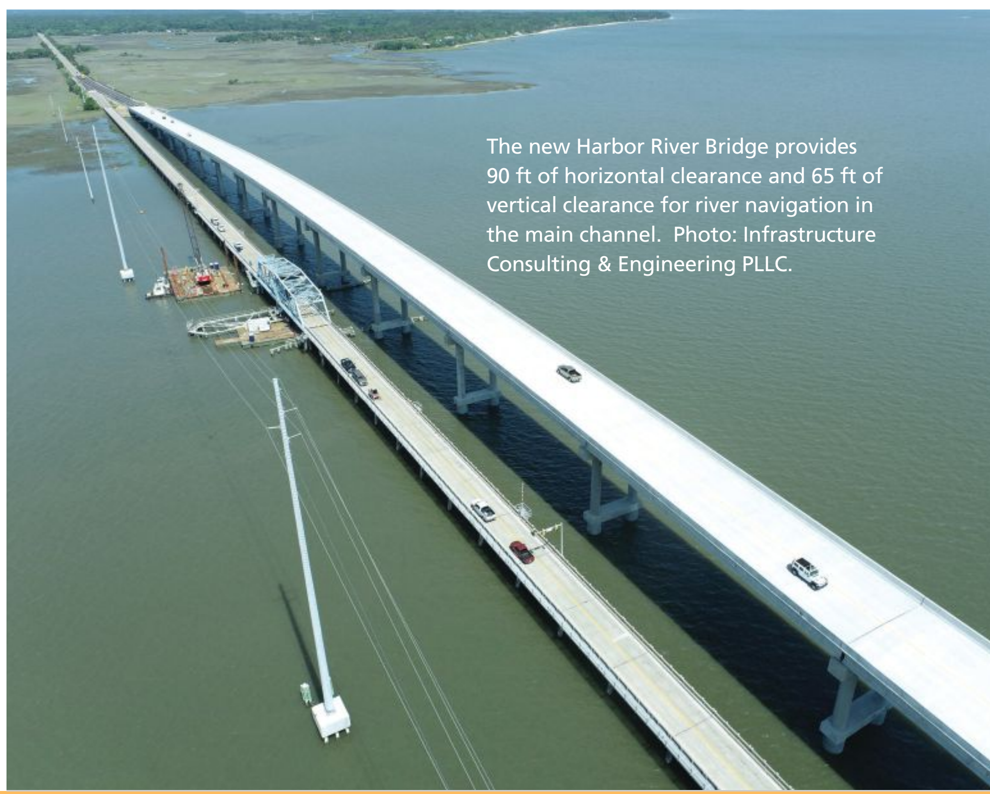
The new Harbor River Bridge is constructed from temporary causeways and by using sectional barges. Photo: Infrastructure Consulting & Engineering PLLC.

The original bridge was extremely narrow and created a safety hazard for motorists. Dangers associated with narrow lanes and shoulders were exacerbated by the volume of wide recreational and camping vehicles traveling to and from nearby Hunting Island. Two such vehicles passing each other on the bridge created a nerve-racking experience. The typical section of the replacement bridge, which features 12-ft-wide lanes and 10-ft-wide shoulders, provides a more comfortable and safer driving experience. The replacement structure has improved the health, safety, and welfare of the community and the traveling public. Additionally, the high-level crossing allows vessels to pass under the bridge without interruption, eliminating delays associated with opening the swing span of the original low-level bridge.

Complex Design Challenges

Two-dimensional modeling of the tidal river and the contributing water currents indicated a significant amount of scour could occur under certain conditions. At some of the tallest bents, the total scour depth was predicted to be approximately 30 ft below the bottom of channel. To address this scour potential, the design team used the 100-year scour profile to design the interior bents for all strength and service limit states, while completely neglecting the contribution of soils above the predicted scour level, to ensure that the new bridge will not be negatively affected by scour over its full 75-year design life (based on the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1]).

Because the Harbor River Bridge is the only means of vehicular access to



The new Harbor River Bridge provides 90 ft of horizontal clearance and 65 ft of vertical clearance for river navigation in the main channel. Photo: Infrastructure Consulting & Engineering PLLC.

SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: 3340-ft-long, 20-span bridge featuring two 12-ft-wide lanes with 10-ft-wide shoulders in each direction, and providing 90 ft of horizontal clearance and 65 ft of vertical clearance for river navigation in the main channel

STRUCTURAL COMPONENTS: 100 Modified Florida BT-78 prestressed concrete beams spanning up to 167.5 ft, cast-in-place reinforced concrete deck, 8-ft-diameter drilled shafts, and 24-in. prestressed concrete piles. Reinforced concrete struts are provided between columns in the river for vessel-impact loads.

BRIDGE CONSTRUCTION COST: $54.7 million

AWARDS: Design-Build Institute of America National Award of Merit; American Council of Engineering Companies (ACEC) Engineering Excellence – National Recognition Award; ACEC of South Carolina National Award, Engineering Excellence, and Engineering Excellence – State Honor Award

Contractor sets the prestressed concrete beams as deck placement continues on another bridge unit. Photo: Infrastructure Consulting & Engineering PLLC.

three barrier islands, the South Carolina Department of Transportation (SCDOT) placed high importance on the longevity of the structure. The design criteria therefore required a seismic pushover analysis (Seismic Design Category C), and the substructure was also required to resist vessel impact in the form of multiple scenarios of loaded barges and towboats traveling at different speeds and tidal conditions. To address these extreme event loading scenarios and ensure that all seismic design requirements were satisfied, the design team used an analysis and design software package to create multiple models of the entire bridge. Seismic detailing techniques, as defined in SCDOT's *Seismic Design Specifications for Highway Bridges*,[2] include butt-welded column and shaft reinforcing bar hoops, shear keys, and minimum bent-cap shelf widths.

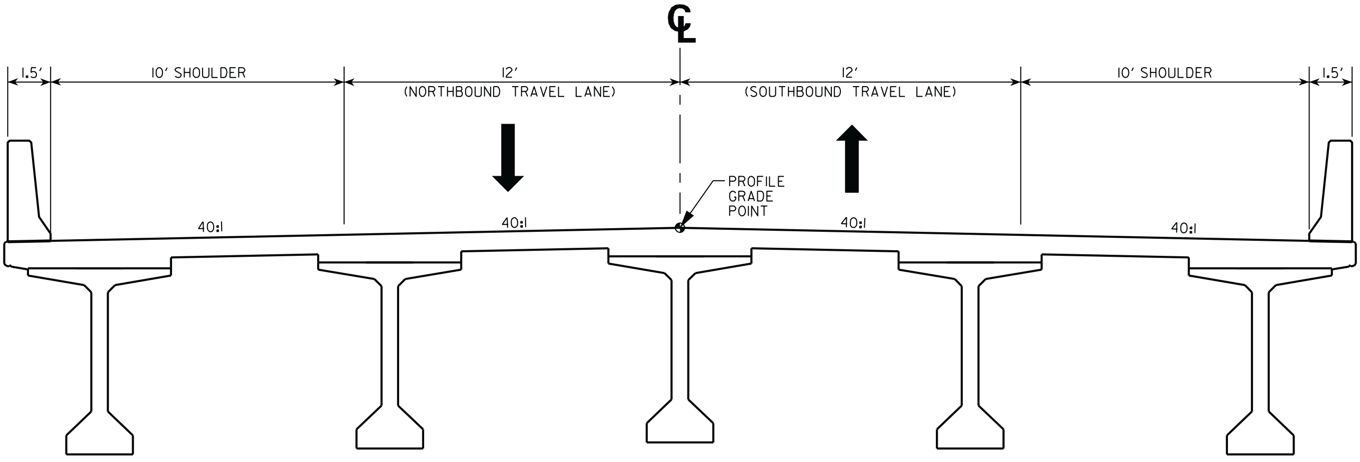
Geotechnical borings taken from the site indicated a high probability of liquefaction during a seismic event. Liquefaction occurs when saturated or partially saturated soil loses shear strength in response to an applied stress, such as ground motion from an earthquake. To mitigate the effects of liquefaction, the design team included a ground-improvement program consisting of driven piles and earthquake drains in the bridge embankments. The piles were designed to meet the settlement performance criteria under the static conditions per the SCDOT *Geotechnical Design Manual*.[3] The earthquake drains—prefabricated vertical drains made of a perforated pipe wrapped with a geotextile filter fabric—were incorporated to prevent liquefaction of the soils surrounding the piles under the design seismic events. These drains have a high-flow capacity that provides a shortened drainage path for the rapid reduction of earthquake-induced stresses in the soil during a seismic event. Seismic models of the bridge also included liquefied cases to ensure that the interior bents could accommodate the predicted loss of soil support.

To address multiple vessel-impact scenarios, the design team used nonlinear finite element analysis software to accurately distribute the massive loads to adjacent bents and fully capture the effects of soil-structure interaction below the groundline. Large reinforced concrete struts (4.5 × 8.5 ft in cross section) were placed at the bottom of the columns within the navigational channel to ensure adequate distribution of vessel-impact loads to adjacent columns and drilled shafts. A fender system was also required in the main channel span to address vessel-impact risks.

Cost-Saving Strategies

The design-build contractor and engineer developed 10 alternative technical concepts (ATCs) for the project to reduce construction and maintenance costs while meeting all of the SCDOT design criteria for the structure. One ATC eliminated the need for closed drainage systems to carry runoff from the bridge deck. These systems often clog, requiring constant

Typical bridge cross section. Figure: Infrastructure Consulting & Engineering PLLC.



Sectional barges were used for construction access and to place the prestressed concrete beams. The prestressed concrete beams and piles were delivered to the project site either by barge or truck. Photo: United Infrastructure Group Inc.

maintenance, and also add significant initial construction costs to the project. Given the overall length of the bridge, the predicted hydraulic spread could not be contained within acceptable limits if a normal 2.0% crown section was used. Consequently, the design team proposed using a crowned section with a slightly steeper 2.5% cross slope to keep the spread within acceptable limits, thereby eliminating the need for any closed drainage systems on the bridge.

Mass Concrete Elements

The project criteria specified that drilled shafts with a diameter of 6 ft or greater were to be considered "mass concrete" elements; such elements require special concrete mixture proportions, special placement parameters, temperature monitoring and control, and testing to ensure the structural integrity of the shafts. Nine interior bents located within the limits of the channel required two 8-ft-diameter drilled shafts each. Therefore, provisions for accommodating mass concrete were required. To limit the maximum temperature difference from the inside to the outside of the shaft to less than 35°F (as required by the project specifications), the design included the placement of cooling tubes within these drilled shafts and the development of special concrete mixture proportions. Computer simulations of the curing process were developed and compared with the actual thermal behavior of the concrete placed in a test shaft. The team used the results to calibrate the computer model and make refinements to concrete placement techniques before constructing the production shafts. This approach ensured that the shafts were not exposed to high temperatures that might result in excessive internal tensile strains and microcracking of the concrete.

Environmental Considerations

On this project, it was critical to protect the natural resources associated with the Harbor River. The design team elected to use prestressed concrete beams to eliminate the long-term maintenance costs associated with structural steel in a marine environment. The team chose a beam type that could accommodate long spans—modified Florida BT-78 beams—to minimize the number of substructure elements required and help meet the environmental commitments. The beams are 78 in. deep, are spaced at 10 ft 1¾ in. on center, and span a maximum of 167 ft 6 in.

To further minimize work in the salt marshes, footings supported by 24-in. prestressed concrete piles were selected for the interior bents outside of the channel limits. Crews constructed these marsh bents from temporary causeways, using sectional barges that could be removed without long-term damage to the marsh ecosystem. Floating barges were used for much of the bridge construction access. Crews used either trucks or barges to deliver the prestressed concrete piles and beams to the site, depending on their location in the final structure.

The design team committed to monitoring the bald eagle nest in the vicinity of the project, implementing best management practices regarding sea turtles and manatees, and removing portions of existing embankments for environmental mitigation. Additional environmental commitments, conditions, and regulatory obligations involved compensatory mitigation (fish habitat mitigation), shellfish restoration, and marine mammal monitoring during demolition blasting. The project team also initiated a robust environmental compliance monitoring plan that would protect the unique and sensitive natural surroundings.

Conclusion

The original Harbor River Bridge was too narrow, in poor condition, and a safety hazard for motorists traveling to and from Harbor Island, Hunting Island, and Fripp Island. The design team faced multiple challenges when designing the replacement, including increased scour potential, seismic design and vessel-collision loads, embankment liquefaction, and environmental constraints. To compensate for coastal conditions and to increase the structure's longevity, the team used resources such as the 100-year scour profile and impact-scenario software to determine the most enduring design. Given the important coastal habitat, the team also made many environmental commitments, such as monitoring a bald eagle's nest and implementing the best management practices for sea turtles and manatees, to minimize the structure's impact on the local ecosystem. The design team provided SCDOT with design submittals that were on-time, efficient, and of high quality. This process led to successful completion of the bridge five months ahead of schedule.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2017. *AASHTO LRFD Bridge Design Specifications,* 8th ed. Washington, DC: AASHTO.

2. South Carolina Department of Transportation (SCDOT). 2008. *Seismic Design Specifications for Highway Bridges*. Columbia, SC: SCDOT. https://www.scdot.org/business/pdf/structural-design/specs_2008.pdf.

3. SCDOT. 2018. *Geotechnical Design Manual*, version 2.0. Columbia, SC: SCDOT.

Lynda Monroe is vice president of marketing for Infrastructure Consulting & Engineering PLLC in West Columbia, S.C.

Transportation Awards Jury

Reggie Holt
SENIOR STRUCTURAL ENGINEER, FEDERAL HIGHWAY ADMINISTRATION, WASHINGTON, D.C.

Bijan Khaleghi
STATE BRIDGE DESIGN ENGINEER, WASHINGTON STATE DEPARTMENT OF TRANSPORTATION BRIDGE AND STRUCTURES OFFICE, OLYMPIA, WASH.

Todd Lang
PE, SE, SENIOR BRIDGE ENGINEER, HDR ENGINEERING, OMAHA, NEB.

SUSTAINABLE DESIGN AWARD AND REHABILITATED BRIDGE

Swift Island Historic Arch Bridge Rehabilitation and Widening

ALBEMARLE, NORTH CAROLINA

Owner: North Carolina Department of Transportation, Raleigh, N.C.
PCI-Certified Precast Concrete Producers: Eastern Vault Company, Princeton, W.Va.; Ross Prestress, Knoxville, Tenn.
Engineer of Record: AECOM, Raleigh, N.C.
General Contractor: PCL, Denver, Colo.

ALL-PRECAST CONCRETE SOLUTION AWARD AND BRIDGE WITH A MAIN SPAN UP TO 75 FEET HONORABLE MENTION

NM 50 Over Glorieta Creek

GLORIETA, NEW MEXICO

Owner and Engineer of Record:
New Mexico Department of Transportation, Santa Fe, N.M.
PCI-Certified Precast Concrete Producer: Castillo Prestress, Belen, N.M.
General Contractor: AUI Inc, Albuquerque, N.M.

NON-HIGHWAY BRIDGE CO-WINNER

I-579 Urban Open Space Cap

PITTSBURGH, PENNSYLVANIA

Owner: City of Pittsburgh, Pa.
PCI-Certified Precast Concrete Producer:
Northeast Prestressed Products, Cressona, Pa.
Engineer of Record: HDR, Pittsburgh, Pa.
General Contractor: Fay, S&B USA Construction, Pittsburgh, Pa.

TRANSPORTATION SPECIAL SOLUTION

Key Crossing Reliability Initiative

BALTIMORE, MARYLAND

Owner: Baltimore Gas and Electric, Windsor Mill, Md.
PCI-Certified Precast Concrete Producer:
Coastal Precast Systems, Chesapeake, Va.
Engineer of Record: Sargent & Lundy, Elkridge, Md.
Structural Engineer: Moffatt & Nichol, Baltimore, Md.
General Contractor: McLean Contracting Company, Glen Burnie, Md.
Project Manager: Burns & McDonnell, Windsor Mill, Md.

View the full 2023 PCI Design Awards digital supplement piece here: **bit.ly/3MB6jY1**

PROJECT

Precast, Prestressed Concrete I-Beams for the Red-Purple Modernization Program

by Emily Hereford and David Depp, Stantec Consulting, and Amelia Johnson, Walsh-Fluor Design-Build Team

With an average weekday ridership of 1.6 million and routes spanning the city of Chicago, Ill., and 35 surrounding suburbs, the Chicago Transit Authority (CTA) is the second-largest transportation system in the United States. The Red-Purple Modernization Program (RPM), which started in 2009 with a vision study, is the largest capital project in CTA's history. It is a multiphased program to improve the 90-year-old infrastructure of the CTA's Red and Purple transit lines along a 9.6-mile stretch of tracks from Belmont Avenue on the northside of Chicago to Linden Avenue in suburban Wilmette. The design-build team was awarded a $2.1 billion contract for phase 1 of the project in 2018 and received notice to proceed in early 2019.

Project challenges have included the need to maintain rail operations during construction while following safe construction practices in a limited work area. CTA looked for a design-build team that would provide the best value while implementing innovative design development and construction methods, and the agency was willing to consider alternative technical concepts (ATCs) that would provide technical solutions equal to or better than the concepts set forth in the technical requirements of the request for proposal. The selected design-build team has used ATCs at several locations, most notably for the precast concrete segmental box girder for the Lawrence to Bryn Mawr Guideway (featured in a Project article in the Spring 2023 issue of *ASPIRE*®) and for the precast, prestressed concrete I-beams for the North Mainline Reconstruction between Belmont Station and Cornelia Avenue.

Precast, prestressed concrete beams on the new structure adjacent to the existing, deteriorating steel structure. Photo: Walsh-Fluor Design-Build Team.

Preceded by the construction of a grade-separated bypass for the Brown line (whose route intersects with the Red and Purple line routes at Belmont Station), the North Mainline Reconstruction is modernizing and realigning

profile

CTA NORTH MAINLINE BRIDGE RECONSTRUCTION FROM BELMONT STATION TO CORNELIA AVENUE / CHICAGO, ILLINOIS

BRIDGE DESIGN ENGINEER: Stantec, Chicago, Ill.

PRIME CONSTRUCTION ENGINEER: Collins Engineers Inc., Chicago, Ill.

PRIME CONTRACTOR: Walsh-Fluor Design-Build Team (a joint venture), Chicago, Ill.

CONCRETE SUPPLIER: Ozinga Ready Mix, Chicago, Ill.

PRECASTERS: I-beams: County Materials Corporation, Janesville, Wis.—a PCI-certified producer; noise barriers: Utility Concrete Products, Morris, Ill.—a PCI-certified producer

Precast, prestressed concrete beams with deck formwork are adjacent to the historic Vautravers Building, which was relocated approximately 30 ft to eliminate a curve in the existing rail alignment. Photo: Stantec.

approximately 1.4 miles of mainline tracks from Belmont Station on the south to Cornelia Avenue on the north.

Design

In the Red-Purple bypass area, the total length of the mainline reconstruction segment is about 1400 ft. This segment carries four mainline tracks—two in each direction (north and south). It includes some track crossovers and a two-track turnout for the Brown line north of Belmont Station.

The existing track substructures consist of multicolumn riveted steel bents—typically with one column beneath each track—and are supported on relatively shallow spread footings. The existing open-deck track uses timber ties supported on two riveted steel girders per track, which span between the bents.

As part of the Chicago Transit Authority's Red-Purple Modernization Program, approximately 1.4 miles of mainline tracks from Belmont Station to Cornelia Avenue are being modernized and realigned. Figure: Walsh-Fluor Design-Build Team.

The CTA project documents designate "permissible area" limits for underground and overhead construction, based on right-of-way property ownership, existing and proposed utility locations, alleys and streets, and parking. Given these limitations, the design-build team has used the request-for-proposal base-case span layout for most spans; however, after CTA approved an ATC, a few spans have been refined or combined to make better use of the beams' capabilities and eliminate some substructures.

All new track structures in this segment use a concrete closed deck and a direct-fixation method to attach the track to raised concrete plinths, per the project requirements. The design team has minimized the use of transverse expansion joints in the deck, based on construction and maintenance considerations.

One of CTA's project goals is to improve noise mitigation for the new track structures, so the project requirements include concrete noise barriers extending 3.5 ft above the top of rail. The design-build team has used precast concrete noise panels at the outer edges of the new deck, with an architectural pattern on the exterior face. Thus, the precast concrete panels serve two purposes—they reduce the noise of the trains for the neighborhood, and their aesthetic design enhances the community.

The original RPM project documents required galvanized steel framing for the new track structures. However, during the prebid phase, the design-build team proposed an ATC to use 36-in.-deep precast, prestressed concrete I-beams for most of the framing in this segment. Advantages presented in the ATC included significant cost savings, shorter construction schedule, reduced future

CHICAGO TRANSIT AUTHORITY, OWNER

BRIDGE DESCRIPTION: 1400-ft-long, 22-span concrete deck bridge—17 spans framed with precast, prestressed concrete I-beams and five spans with steel beams—carrying four tracks of the Chicago Transit Authority's Red and Purple lines

STRUCTURAL COMPONENTS: One hundred sixty 36-in.-deep precast, prestressed concrete I-beams with span lengths of 41 to 77 ft, minimum 10-in.-thick cast-in-place concrete deck, 2800 ft of precast concrete noise panels, cast-in-place pier caps, columns, and drilled shafts or micropiles

BRIDGE CONSTRUCTION COST: $1.2 billion

Some of the 36-in.-deep precast, prestressed concrete beams were stored on site, where fixed bearings and fall protection were installed before erection. Photo: Walsh-Fluor Design-Build Team.


Precast, prestressed concrete beams after erection but before deck placement. The beams span up to 77 ft, with up to thirty-four 0.6-in.-diameter prestressing strands used for the longest spans. Photo: Walsh-Fluor Design-Build Team.

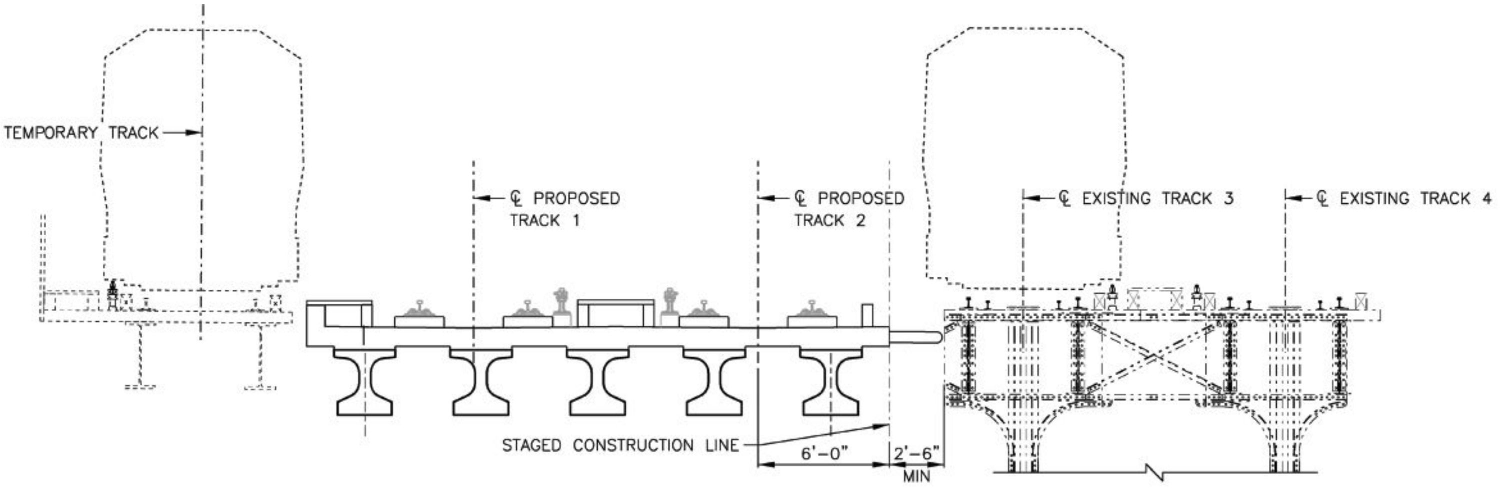
maintenance and inspection efforts, and reduced noise from train operation. When the CTA accepted the ATC for precast, prestressed concrete I-beams, the agency required that the design-build team address several issues, including auxiliary negative current return, stray-current control, and 100-year service life with corrosion resistance.

Precast, prestressed concrete I-beams are used for 17 of the 22 new concrete deck spans. Considerations, including vertical clearance over an electric power substation building and Clark Street as well as facilitating connections to existing framing, dictated the use of steel for the other five spans. Both precast, prestressed concrete and steel I-beams are used in four "hybrid" spans near the Brown line turnout to accommodate flared framing and staged construction. In the hybrid spans containing adjacent steel and precast, prestressed concrete beams, glass-fiber-reinforced polymer reinforcement is used instead of steel in the deck to address electrical grounding and stray current as well as considerations for the precast, prestressed concrete beams.


Erection of a precast, prestressed concrete I-beam. Most of the beams were erected at night to limit the project's impact on rail operations. Photo: Walsh-Fluor Design-Build Team.

The 36-in.-deep precast, prestressed concrete I-beams have a section commonly used by the Wisconsin Department of Transportation (WisDOT), with flange widths of 34 in. (top) and 30 in. (bottom) and web width of 6½ in. The design team chose this section because they determined that the WisDOT beams are slightly more efficient than a similar Illinois Department of Transportation section and the precaster had forms available for both options. The beam design uses a concrete strength of 8000 psi and a tensile stress limit of zero for the service dead-load and live-load case, per the American Railway Engineering and Maintenance-of-Way Association's requirements. The beam span lengths range from 41 to 77 ft, and up to thirty-four 0.6-in.-diameter prestressing strands are used for the longest spans. The beams act compositely with the 10-in.-thick cast-in-place concrete deck. The beams are not continuous over the piers, but the deck is continuous over most piers to eliminate expansion joints.

New substructures consist of concrete multicolumn bents. Typical bents allow the beams to bear on top of the concrete cap; however, a few bents use an inverted-tee cap design where vertical clearance is required for alleys or streets.



Cross section showing stage 2 construction for tracks 1 and 2 and accommodations for existing rail traffic. Figure: Stantec.

Per contractor preference, foundations are 4- or 5-ft-diameter reinforced concrete drilled shafts at locations where there is adequate construction clearance. Grouted steel micropiles are used at other locations where shaft construction is limited by vertical or horizontal constraints such as adjacent or overhead structure elements. Typical drilled shafts on this project have a belled end to bear on a hardpan soil layer about 65 ft below grade, and micropiles extend to solid bedrock about 85 ft below grade.

The design-build team developed a complex staging sequence for demolition and construction to keep two tracks operational during construction. The staging requires temporary alignment shifts at the north and south ends of the reconstruction segment. The staging is especially complicated in the very tight working area between Belmont Station and the Brown line turnout, and the structural framing layout in these spans was developed to accommodate the staging.

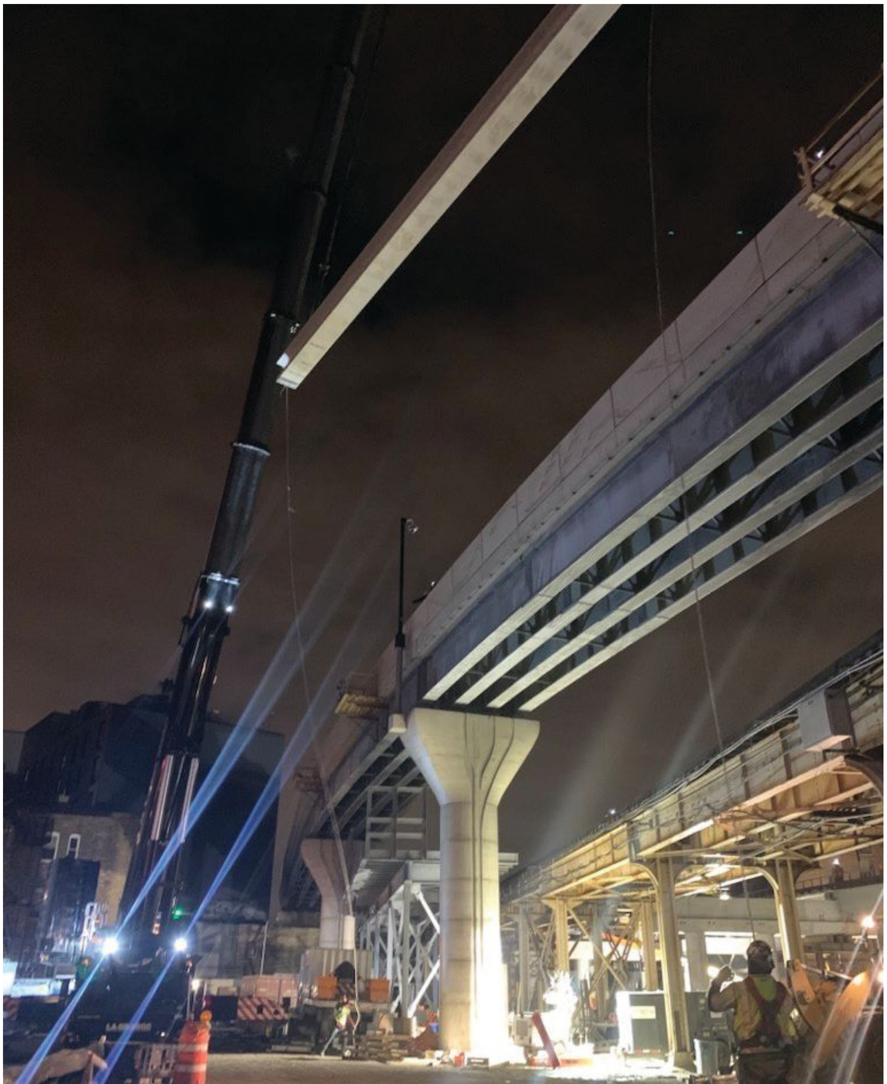
The placement of CTA structures next to properties throughout the transit system has posed multiple challenges for design and construction. When the original tracks used by the Red and Purple lines were constructed, they were routed around buildings where space was available. In the project area, the team needed to straighten a curve in the tracks to increase operating speed and reduce travel time. To accommodate this change, CTA acquired adjacent lots before issuing the notice to proceed. The historic Vautravers Building, a three-story building constructed in 1894, was adjacent to the tracks, and the project scope included relocating this building approximately 29 ft west of its current location. It was ultimately moved approximately 30 ft west and 4 ft south to align the building facade with other historic buildings on the street and accommodate right-of-way requirements.

Interdisciplinary coordination is a key part of this project, with the teams using a three-dimensional model to aid in coordination. Train operations require sophisticated electrical systems for traction power, signals, and communication, and the cables for these systems run below the deck and through raised footwalks on top of the concrete deck. Coordinating cable routing with the structural design was a significant challenge, and in many locations the cables pass through sleeved openings in the cast-in-place concrete deck and precast, prestressed concrete beams.

Construction

An RPM requirement is to maintain rail operations and minimize inconvenience for CTA customers. The mainline track

Erection of precast, prestressed concrete beams next to the Brown line flyover bridge occurred mainly at night. Photo: Walsh-Fluor Design-Build Team.



The north mainline construction for tracks 1 and 2 under the flyover structure. This view shows, from left, the temporary tracks; the precast, prestressed concrete beams that will carry tracks 1 and 2; tracks 3 and 4 on the existing structure; and the tracks on the flyover structure. Photo: Chicago Transit Authority.

structure carries four tracks and includes an at-grade crossing of the Brown line. The first stage of the project required construction of a curved steel girder flyover bridge to eliminate the at-grade crossing, as well as the construction of a temporary track structure to accommodate southbound Brown line travel from the Ravenswood structure to the mainline structure. This arrangement has allowed CTA to move into a two-track operation so that construction could begin on tracks 1 and 2 of the mainline structure during stage 2. Upon completion of tracks 1 and 2, train traffic will shift to them, and construction will begin on tracks 3 and 4 during stage 3. Train operations are scheduled to begin on tracks 1 and 2 in September 2023, and the overall project is scheduled for completion in 2025.

The eighty 36-in.-deep precast, prestressed concrete beams for stage 2 (the western half) were fabricated in May 2022, and delivery began in June 2022. Beam fabrication for the remaining eighty beams for stage 3 (the eastern half) will begin in late 2023.

Beam erection was also done in stages. The original intention was to install beams from north to south; however, due to other on-site circumstances, the beams were installed as the substructure was available. This modification to the original erection plan was easily accommodated because all precast, prestressed concrete materials were cast at the beginning of the erection.

Some precast, prestressed concrete beam installation challenges were due to the project's previous stage of construction, in which the flyover bridge for the northbound Brown line was built while the southbound Brown, Red, and Purple lines were actively running at deck elevation. To mitigate the project's impact on CTA riders, most of the beams were installed at night. The use of precast, prestressed concrete beams made it possible to install the beams over and then under the flyover and between the active tracks during the brief work windows between live trains.

Installation of the precast, prestressed concrete beams for stage 2 was completed by January 2023. The superstructure, trackwork, systems, and new track tie-ins are expected to be completed in late fall 2023, when the RPM will transition into the next phase.

Stage 2 construction between the existing steel structure (left) and the temporary steel structure (right). Photo: Stantec.

Emily Hereford is an associate and project lead with Stantec Consulting in New York, N.Y., and David Depp is a senior project manager and structural engineer with Stantec Consulting in Lexington, Ky. Amelia Johnson is a senior project manager and construction manager with the Walsh-Fluor Design-Build Team in Chicago, Ill.

Show Gratitude for the Past and Invest in the Future

by Dr. Brandon Ross, Clemson University

We have an amazing industry. We have the privilege of designing, building, inspecting, maintaining, and repairing bridges! Our work connects communities, people, and commerce, while also ensuring public safety and the efficient use of economic and environmental resources. Our expertise, "building bridges," is even used as a metaphor for closing gaps between different ideas, cultures, and groups.

While the products of our industry are impressive, the people of our industry are equally impressive. Working in the concrete bridge industry has put me in contact with some of the most brilliant, visionary, dedicated, and humble people. In this short piece, I want to celebrate a few of the people in our industry who have inspired me and helped me to build a rewarding career. I hope that after reading this, you are inspired to express gratitude for your mentors and extend generosity to your mentees.

In the spring of 1997, there were two instructors teaching the Mechanics of Materials course at the University of Wyoming. My decision to choose the section taught by Dr. Charles Dolan ended up being such a fateful decision! After the first class the instructor invited me and another student (Rebekah Burke, who is now a faculty member at The Citadel) to visit his office after class. I was terrified. What had I done to deserve such a request? At the meeting, the professor invited us both to help in the structural engineering lab as undergraduate research assistants. We accepted and were quickly introduced to the wonders of reinforced and prestressed concrete. I can draw a straight line from that invitation to my current role as a faculty member at Clemson University. This professor made an outsized impact on my life and career, and I try to do the same for my students. Each year I invite one or two undergraduates to work in my lab.

Investing in our future industry workforce. Here, Dr. Ross works with high school students during a summer camp. Photo: Clemson University.

The next person I want to highlight is a recent student whom I will call Leslie (name changed). Leslie asked insightful questions during lectures, was helpful and friendly to her classmates, and was diligent in her preparation for tests. She was just the kind of student that teachers love to have in class. At one point in the semester, Leslie stopped by my office to let me know she would miss classes the next week because she needed to attend to a difficult family situation. We chatted for a few minutes, and I shared the strategies I used for coping with a similar experience. During the chat, Leslie also told me a little bit of her background and the challenges she faced as a first-generation college student. A week later, Leslie returned to class and ended the semester strong. We have stayed in touch as she has started her career as a structural engineer. She is thriving and is one of my heroes. We are fortunate to have her as a member of the structural engineering profession.

I will end by challenging you, the reader, to contact a mentor and express your gratitude. I also challenge you to be generous and giving to the next generation. Our past is great and our future is bright! As we go about our work of designing and building bridges, let's also invest in the future professionals of our industry.

PROJECT

Sixth Street Viaduct in Los Angeles Creatively Melds Past and Present

by Michael Jones, HNTB

Aerial view of the Sixth Street Viaduct at sunset, with the downtown Los Angeles, Calif., skyline to the west and San Gabriel Mountains to the north. Photo: HNTB, © Core-Visual.

The Sixth Street Viaduct was the longest and best known of the 15 historic concrete bridges built in Los Angeles, Calif., between 1909 and 1934. This viaduct and the other 14 bridges represented some of the finest examples of the City Beautiful movement that swept across the United States from the 1890s through the 1920s. An icon beloved by the community, the Sixth Street structure served as a backdrop for numerous movies, TV shows, commercials, and music videos, as well as countless personal stories.

Unfortunately, the Sixth Street Viaduct had an alkali-silica-reactive aggregate. When a seismic retrofit project was intiated to improve the viaduct's seismic resiliency, the project team found that arresting the deterioration in the cement paste was not possible. Thus, the project scope evolved into a full bridge replacement.

The lead agency for the replacement, the City of Los Angeles Bureau of Engineering (BOE), held an international design competition to find a worthy replacement for the popular bridge. The winning design resembles the architecture of the original historic bridges, complete with a concrete tied-arch design and efficient thin profiles made possible by a network of hangers that support the bridge deck beneath.

Dubbed the "Ribbon of Light," the new viaduct opened in July 2022 with a three-day celebration held on the bridge deck. It was instantly accepted by the community as an elegant and worthy replacement of its predecessor. It is a unique structure to be sure. No other bridge in the world is designed with 10 contiguous, tied network arches that interact as a single unit through an uninterrupted, continuous edge girder tie. The final 12-span design includes two continuous cast-in-place, post-tensioned concrete box-girder approach spans and measures 3058 ft long, abutment to abutment. The 100-ft-wide bridge is supported on concrete Y-bents. The deck includes two lanes of traffic in

profile

SIXTH STREET VIADUCT / LOS ANGELES, CALIFORNIA

BRIDGE DESIGN ENGINEER: HNTB Corp., Los Angeles, Calif.

OTHER CONSULTANTS: Architectural consultants: Michael Maltzan Architecture, Los Angeles, Calif., and Dissing+Weitling, Copenhagen, Denmark; construction engineer: COWI North America, North Vancouver, BC; construction management: T. Y. Lin International, Los Angeles, Calif.; geotechnical engineer of record: Earth Mechanics Inc., Fountain Valley, Calif.

PRIME CONTRACTOR: Skanska USA Civil West and Stacy and Witbeck Joint Venture, Riverside, Calif.

CONCRETE SUPPLIERS: Primary supplier: CEMEX, Los Angeles, Calif; backup supplier: Robertson's Ready-Mix, Corona, Calif.

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

OTHER MATERIAL SUPPLIERS: Isolation bearings: Earthquake Protection Systems, Vallejo, Calif..; reinforcing steel fabricator: LA Steel Services, Corona, Calif.; expansion joints: DS Brown, North Baltimore, Ohio; cast-in-drilled-hole pile foundations: Condon-Johnson & Associates, Los Angeles, Calif.

The new Sixth Street Viaduct provides multimodal transportation with separate travel ways for vehicular, bicycle, and pedestrian traffic. The arch ribs are canted outward at 9 degrees and provide picture-perfect views of the downtown skyline. Photo: HNTB, © Core-Visual.

each direction along with two Class IV protected bicycle lanes, as defined by the California Department of Transportation (Caltrans), and two 8- to 14-ft-wide walkways along both edges of the bridge. The nominal distances between Y-bent centers vary from 240 to 313 ft. The actual arch span lengths are shorter due to the use of a jump span over each Y-bent between the arch spans, with a minimum arch span of 191 ft and a maximum of 250 ft.

The new viaduct carries traffic over the Los Angeles River, two railroad corridors, U.S. Route 101, local city streets, and a future 12-acre park that will be constructed beneath the viaduct. To fully integrate the viaduct with the park and surrounding community, five sets of stairways and two pedestrian ramps, including an intriguing helical ramp, provide direct access to the park and surrounding community.

Why Cast-in-Place Concrete?

The BOE made the decision to move forward with a concrete bridge to be consistent with the original historic bridges while minimizing maintenance costs. Cast-in-place concrete also facilitated the aesthetics of the design concept because the material could be effectively used to achieve the structure's complex geometry. The arches needed to flow seamlessly into the Y-bents to integrate the viaduct with the surrounding community and the park below by providing perfect geometric support for the descending stairways. The varying shapes and sizes of the arches were anything but repetitive, and concrete can be formed into any shape desired.

Cast-in-place concrete also offered other practical benefits. The concrete could be batched at a plant located within 3 miles from the project site. In contrast, the nearest steel bridge fabricators with the expertise to fabricate complex bridge components are located outside

Helical bicycle/pedestrian ramp. Two ramps and five sets of stairways are provided to fully integrate the viaduct with the future park planned below the viaduct. Photo: HNTB, © Core-Visual.

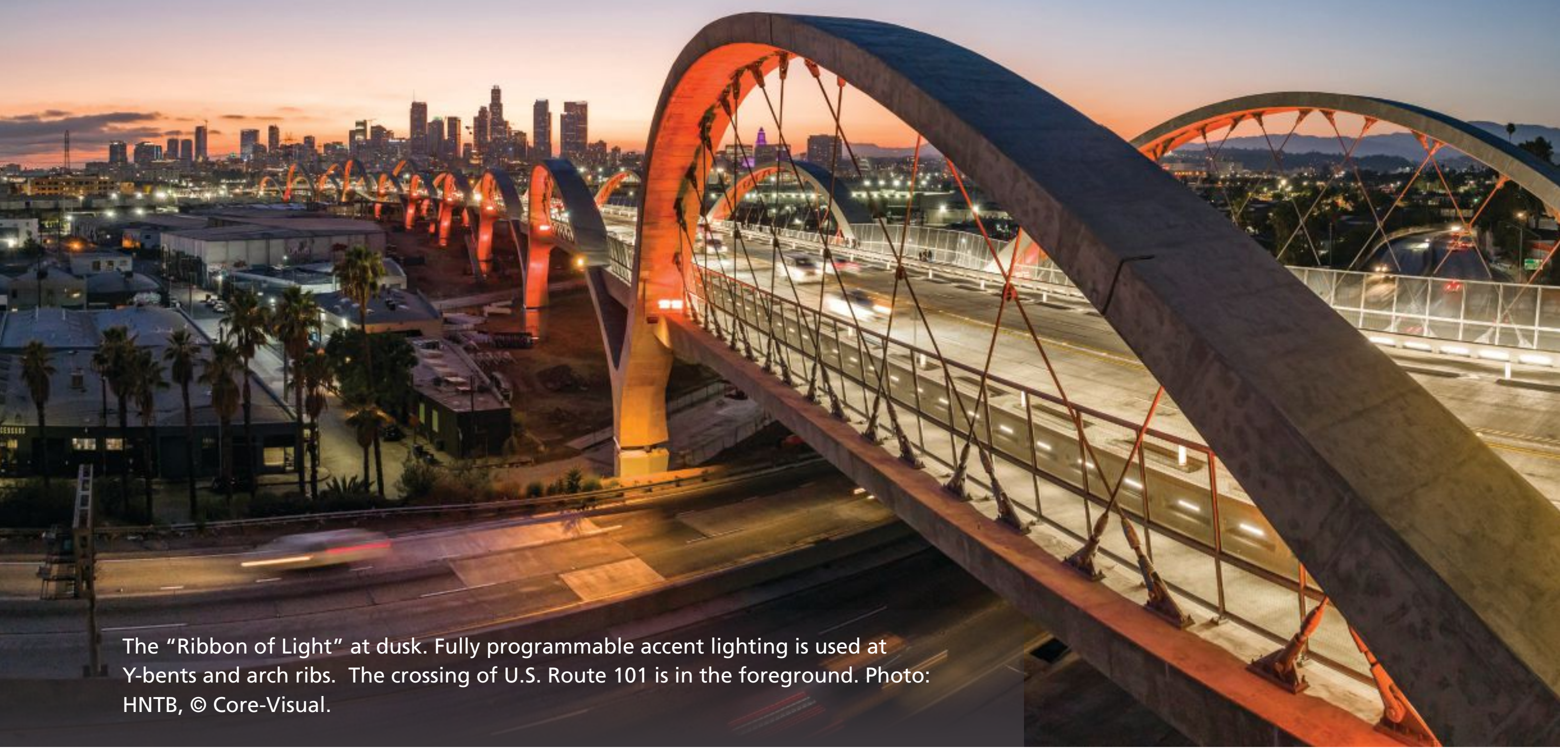
CITY OF LOS ANGELES BUREAU OF ENGINEERING, OWNER

BRIDGE DESCRIPTION: 12-span, 3058-ft-long, 100-ft wide bridge consisting of 10 continuous concrete tied arch spans supported on concrete Y-bents and two continuous post-tensioned, cast-in-place concrete box-girder approach spans

STRUCTURAL COMPONENTS: Ten-span continuous cast-in-place tied network arch with nine cast-in-place jump spans, two-span cast-in-place post-tensioned box girders, five cast-in-place concrete stairways, two cast-in-place box-girder pedestrian/bicycle ramps, one cast-in-place concrete helical pedestrian/bicycle ramp, cast-in-place Y-bents, columns, and abutments, cast-in-drilled-hole pile foundations

BRIDGE PROGRAM CONSTRUCTION COST: $588 million

AWARDS: American Concrete Institute Southern California Chapter's 2022 Charles J. Pankow Jr. Award; American Council of Engineering Companies (ACEC) Grand Award Winner; ACEC California 2023 Engineering Excellence Honor Award and Golden State Award (the highest honor); American Public Works Association's Southern California 2022 BEST Award for a transportation project in a city with a population greater than 200,000; *The Architect's Newspaper*'s 2022 Best of Design, editor's pick for infrastructure; Civil + Structural Engineer Media's 2022 most popular infrastructure project (voted on by the public); Envision Platinum Award for Sustainability; Los Angeles Business Council 2022 Architectural Awards – Civic Award; *Roads & Bridges*' top 10 bridges list for 2022; WTS International: 2022 WTS-LA Innovative Transportation Solutions Award; Post-Tensioning Institute's 2023 Award of Excellence, Bridge Category



The "Ribbon of Light" at dusk. Fully programmable accent lighting is used at Y-bents and arch ribs. The crossing of U.S. Route 101 is in the foreground. Photo: HNTB, © Core-Visual.

of California. Additionally, the hoisting necessary to construct a cast-in-place structure could be performed with a fleet of truck cranes that were easier to mobilize and maneuver than larger crawler cranes. The shorter booms of the truck cranes would also be more appropriate for work around the power transmission lines that run along the river and for operations within the restricted working areas throughout the project site.

Nevertheless, the project team studied the use of steel floor beams to ascertain whether they would offer any potential cost savings. Given the 100-ft width of the bridge, steel floor beam framing would be about 70% of the total superstructure steel if the entire superstructure, except for the concrete deck, were framed in steel. In the end, studies determined that cast-in-place concrete was the best choice for the viaduct in terms of both cost and aesthetics. Additionally, the expected reduction in dead load between steel and concrete options was not as significant as first expected due to the efficiency of the tied-arch superstructure combined with the Y-bent substructure. The dead load of a typical arch span section with 3-ft-deep edge girders was 195 lb/ft^2, compared with approximately 360 lb/ft^2 for a comparable cast-in-place box girder spanning 300 ft between foundation elements.

Seismic considerations were another concern, particularly when considering the use of steel arch ribs in combination with the concrete substructure. In that type of design, the steel-to-concrete transition connections would have been inordinately complex, in large part due to the high seismicity of the project site. One option was to place the transition some distance above the deck level, to avoid possible seismic hinging locations, but that option lacked the desired aesthetics.

The design team also considered the use of precast concrete floor beams, but they determined that the cast-in-place option was more economical. Cast-in-place edge girders were clearly advantageous for economy,

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

The original Sixth Street Viaduct was a rare bridge, recognized by millions of people around the world as the background of memorable scenes in dozens of movies and TV shows. However, almost no one knew its name; all they knew was that it was somewhere in Los Angeles. What made the bridge so recognizable was the paired half-through arches spanning the Los Angeles River that were joined in gull-wing fashion. When it became necessary to replace this memorable and unique bridge, the city's Bureau of Engineering set out to create an equally noteworthy replacement. It succeeded.

The design of the new bridge extends the gull-wing half-through arch theme to 10 of the 12 spans. The spans vary in length, but the span-to-rise ratio is kept roughly the same, so the arches vary in height. The result is a new, lively, blocks-long scalloped ribbon within the Los Angeles skyline. The arches are continuously lighted, so that the scalloped ribbon stays visible at night. In a final stroke of genius, the arches are unbraced and lean back from the edge of the roadway at a 9-degree angle, seeming to open up the driver's view of the Southern California sky.

The designers left the arches themselves and their gull-wing Y-bents as pure concrete shapes generated by the fundamental geometry of the bridge. There is no additional embellishment, and none is required, but some remarkable engineering innovation was necessary to make the whole thing work in this active seismic area. As a final touch, the designers attached the stairs and ramps as clearly separate elements, differentiated from the bridge itself by material and shape.

This bridge is a masterpiece. I predict that it will become the background of memorable scenes for numerous new movies and TV shows. All who were involved in its design and construction have the right to be proud.

Because Isolation bearings are located within the vertical portion of the Y-bents, the team developed a new seismic isolation design methodology. Photo: HNTB, © Core-Visual.

Steel plate expansion joints developed by the California Department of Transportation and modified for the viaduct are provided at each abutment, making the viaduct a 3058-ft-long continuous structure. The joints allow seismic movement of up to 30 in. in any direction. There is a sacrificial rubber seal at the back of each plate joint. Gaps to accommodate seismic movements can be seen between the arches and abutment. Photo: HNTB.

constructability, seismic integrity, and aesthetics. Once falsework was needed for edge girders, the practical construction option was to connect opposing edge-girder falsework to provide a falsework platform across the entire bridge width to support cast-in-place floor beams.

Seismic Challenges

Although cast-in-place concrete was the preferred material and construction technique, designing the viaduct to withstand a 1000-year seismic event in a high seismic area was a formidable challenge. A particular concern was the arch ribs. Arch rib bracing was not an option given the width of the structure and the architectural goal of opening up the deck, which included canting the arch ribs outward at 9 degrees. As one crosses the viaduct, whether by bus, automobile, bicycle, or on foot, the arch ribs provide picture-perfect views of the downtown skyline to the west and the San Gabriel Mountains to the north.

Computer models revealed that the arch ribs above the deck would respond with unacceptably large lateral displacement when subjected to anticipated seismic ground motions. These concerns led the project team to investigate seismic isolation. They noted that the viaduct's architecture prohibited following standard practice of placing the isolators at the top of the substructure, just below the superstructure. The arch

Stairways are supported from the superstructure deck and a lower canted stairway column. The bottom of the stairway is cantilevered and floats above finish grade, permitting unrestricted seismic displacements in any direction. Photo: HNTB.

ribs needed to flow continuously into the Y-bents, which provide geometric support for the stairways. The bearings would have severed the continuity between the arch ribs and the upper arms of the Y-bents.

Instead, the team chose to place the isolation bearings within the vertical portion of the Y-bent columns. Placing the isolators within the vertical height of the supporting columns was unprecedented for a bridge, but this novel approach led to a fundamental change in the application of seismic isolation by the design team and a new seismic-isolation methodology.

Seismic isolation is used to reduce or eliminate expected damage from seismic events and therefore will vastly improve the post-earthquake functionality of a structure. However, there are no guide provisions that specifically address protection of the bearings themselves. The new approach selected by the design team is succinctly described as "the isolation bearings protect the structure while the structure protects the bearings." This new methodology requires the structure to also be designed as a nonisolated structure. Should seismic displacements within the isolation bearings exceed the 1000-year seismic event displacements by a factor of about two, the bearings stiffen rapidly and activate a secondary earthquake-resisting system. The isolation bearings were reconfigured to facilitate this new methodology. This is a "belt and suspenders" system that makes bearing failure and/or unseating within the column virtually impossible.

The use of isolator bearings allowed the viaduct to be configured as a continuous structure with expansion joints only at each abutment for a continuous length of 3058 ft. This led to further innovations, including the first use of Grade 80 concrete reinforcement on a California bridge. Caltrans had been studying Grade 80 reinforcement but had not yet approved its use pending further verification of ductility performance in plastic hinge regions. For the Sixth Street Viaduct, its use was limited to capacity-protected members that form the secondary earthquake-resisting system—that is, the Y-bent members above and below the isolation bearings. Because the secondary system would only be engaged as a backup to the isolation system, this project was an optimal opportunity to introduce Grade 80 reinforcement in a California bridge. Importantly, the use of Grade 80 reinforcement resulted in cost savings because larger member sections and more reinforcement would have been required if Grade 60 reinforcement had been used.

Now open to the public, the new Sixth Street Viaduct has exceeded BOE's goal of delivering an iconic replacement for the original beloved Sixth Street Bridge that provides unprecedented seismic safety. The replacement viaduct, which is already a recognized backdrop for the city's bustling film and music industry, is expected to be an iconic presence in Los Angeles for the next 100 years.

Michael Jones is a principal engineer and associate vice president at HNTB in Oakland, Calif.

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.com.

IN THIS ISSUE

https://www.asbi-assoc.org/index.cfm/2022-Student-Competition
The Perspective on page 14 discusses the importance of mentoring and uses the American Segmental Bridge Institute's (ASBI's) student competition as an example of industry outreach. This web page provides more information about the competition, as well as two ASBI videos: "An Introduction to Today's Concrete Segmental Bridge Technology" and "Overview of Segmental Bridge Construction."

https://www.concreteconstruction.net/projects/infrastructure/historic-franklin-avenue-bridge-rehabilitation_o
As presented in the Focus article on page 6, Kraemer North America rehabilitated the historic Franklin Avenue Bridge over the Mississippi River in Hennepin County, Minn., using precast concrete elements and ultra-high-performance concrete to meet the demands of an accelerated schedule and provide a durable, long-term solution. This web page provides additional information about the project and a video with highlights of the reconstruction.

https://www.cbsnews.com/pittsburgh/video/final-beams-for-fern-hollow-bridge-start-arriving-at-construction-site/#x
The video at this link shows multiple views of the beam delivery for the new Fern Hollow Bridge in Pittsburgh, Pa. As described in the Project article on page 16, the beam delivery required the truck to be driven backward for a mile and attracted attention from neighborhood residents and the media. The new bridge was opened to traffic in December 2023, less than 11 months after the previous bridge collapsed.

https://www.transitchicago.com/rpm/rpb
The Project article on page 32 discusses precast, prestressed concrete I-beams for the Chicago Transit Authority's Red-Purple Modernization program. This multiphase improvement program includes the Red-Purple Bypass Project. The web page at this link shows "before and after" images that showcase the key role that concrete is playing in the improvements.

https://www.hntb.com/projects/sixth-street-viaduct-replacement
The new Sixth Street Viaduct in Los Angeles, Calif., is featured in the Project article on page 38. Ten concrete tied-arch spans are combined with two prestressed concrete box girder approach spans to carry traffic over the Los Angeles River, two railroad corridors, U.S. Route 101, city streets, and the site of a 12-acre park that will be constructed beneath the viaduct. This is a link to the project website, which features additional information about the project and many photos.

https://www.pgh-sea.com/index.php?path=i5-ucp
The Concrete Bridge Technology article on page 48 describes the Interstate 579 Urban Open Space Cap project in Pittsburgh, Pa. This project includes a bridge structure using prestressed concrete box beams to support a park that features performance and green spaces, integrated local art, and an amphitheater. Follow this link to learn more about this project that reestablishes the connection between the Lower Hill neighborhood and downtown Pittsburgh.

https://www.fhwa.dot.gov/bridge/concrete/hif19067_Nov2021.pdf
This is a link to the *Lightweight Concrete Bridge Design Primer*, which is the topic of the FHWA article on page 59. In addition to outlining the benefits of lightweight concrete, the primer discusses design considerations, specifications, and example projects.

Increasing the Success of Concrete Repairs through Education and Certification Courses

by Dave Fuller, International Concrete Repair Institute

Repairing and restoring concrete structures are important and challenging responsibilities. Unfortunately, many concrete repairs fall well short of their anticipated service lives. Before a repair is initiated, a study must be undertaken to determine the root cause of the concrete damage and possible implications to the structure. Repairing concrete structures involves many complex factors, including choosing the most appropriate material and application method for the project, staging, creating safe workspaces, properly preparing the repair substrate and surface, and accounting for site variables such as weather conditions and access. These factors can all influence the outcome of a concrete repair project. Having properly educated, skilled field personnel on site to install, supervise, and provide quality control for concrete repair installations has a positive effect on the success of the project and how long the repair will last.

Industry organizations like the International Concrete Repair Institute (ICRI)—the only professional association dedicated to concrete repair, restoration, and protection—offer means to educate stakeholders in the concrete repair industry to properly specify and install repair materials. A leading program in the industry is ICRI's Concrete Surface Repair Technician (CSRT) program (**Fig. 1**).

Participants in the CSRT program learn about concrete repair inspection and material tests, types of concrete deterioration, and types of repair materials and methods, as well as the requirements for a quality concrete surface repair. The program has two components: the Education Course and the Certification Course. For a specifier, the courses provide a better understanding of the concrete repair process. With topics ranging from selecting the right materials and installation methods for a specific project to performing material testing in the field, these courses provide valuable education for anyone involved in concrete repair.

Education Course

The Education Course is an online program for those who wish to gain fundamental knowledge and learn best practices in concrete surface repair. It provides participants with practical knowledge in both the science and craftmanship of concrete repair. Consisting of five self-directed modules, the Education Course can be accessed and completed on any device. To successfully complete the course, one must finish all five online training modules and pass a graded exam for each module.

The first module provides students with an understanding of concrete and the factors that contribute to concrete deterioration, including corrosion of reinforcing steel, which is one of the leading causes.

International Concrete Repair Institute

The International Concrete Repair Institute (ICRI) was formed in 1988, when the organizing members established its purpose: "to improve the quality of concrete restoration, repair, and protection through education of, and communication among, the members and those who use its services." Today, ICRI—a member of the National Concrete Bridge Council—offers education, certification, networking, and useful publications for indviduals involved in concrete repair.

Figure 1. Concrete Surface Repair Technician online program. All Figures: International Concrete Repair Institute.

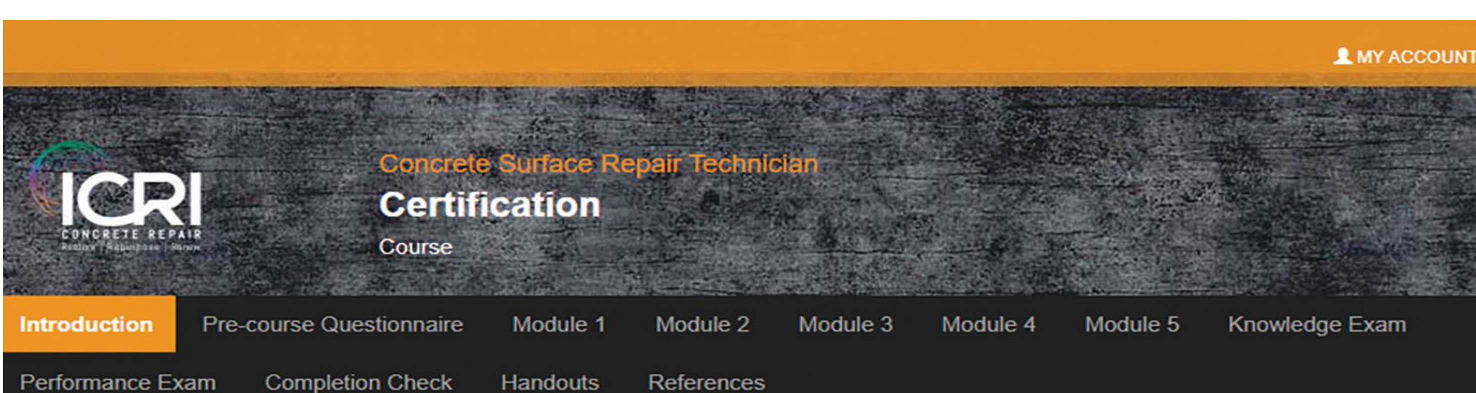


Figure 2. Identifying delaminated concrete using a sounding technique.

Many concrete repairs fail because the deteriorated concrete was not completely removed and the existing substrate was not properly prepared before applying a repair material.

Module 2 covers how to identify and remove areas of concrete deterioration (**Fig. 2**), best practices for repairing and replacing reinforcement, and proper preparation of the concrete substrate.

In the third module, students learn about the various methods of repair and the important physical properties of repair materials that must be evaluated during the material selection process.

The last two modules cover preplacement and postplacement project inspection. Students are shown how to use preplacement and postplacement checklists for quality control on a concrete repair project.

Certification Course

The second component of the program, the CSRT Certification Course, is for individuals who want to become qualified inspectors of concrete repair projects. To achieve certification, candiates must complete the CSRT Education Course and pass an in-person or virtual performance exam to demonstrate the proper use of ASTM testing procedures (**Fig. 3**).

Summary

ICRI's CSRT program enables anyone in the concrete repair industry to increase their knowledge and skills in concrete repair. Whether you are new to the industry or want to build on your existing knowledge, completing this program can help you gain the expertise needed to raise the rate of success on concrete repair projects.

Dave Fuller is the technical director of the International Concrete Repair Institute in Jupiter, Fla. He is a subject matter expert in concrete repair, coatings and sealers, waterproofing, flooring systems, and concrete repair materials, and has delivered technical presentations and hands-on workshops for numerous ICRI local chapters throughout the United States and Canada.

Figure 3. To successfully complete the Concrete Surface Repair Technician Certification Course, candidates must pass a performance exam. This exam may be taken in person (left photo) or virtually with a video submission (right photo).

Calculation of Prestress Loss and Beam Concrete Stress Due to Shrinkage of Deck Concrete

by Richard Brice, Washington State Department of Transportation

The American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] refined estimates of time-dependent prestress losses (LRFD Eq. 5.9.3.4.1-1) includes a term for prestress gain due to shrinkage of deck concrete Δf_{pSS} (LRFD Eq. 5.9.3.4.3d-1). This term accounts for the elongation of the prestressing strand due to the mechanical action of deck concrete creep and shrinkage as well as the time-dependent change in prestressing force due to creep of the beam concrete induced by the same mechanical action. The introduction of this gain in prestress as part of the total prestress loss has caused a lot of confusion and is often misapplied in design calculations for pretensioned beams.

Design examples in Chapter 9 of the upcoming fourth edition of the Precast/Prestressed Concrete Institute's *PCI Bridge Design Manual*[2] introduce a more rational method of stress analysis by using transformed section properties appropriate to the time when the prestressing force and *external* loads are applied. Gross (nontransformed) concrete section properties are used for redistribution of *internal* forces due to time-dependent prestress losses from creep and shrinkage of concrete and relaxation of prestressing reinforcement. The use of nontransformed section properties provides a reasonable approximation for the net concrete section properties required for initial strain analysis.

An appendix to Chapter 8 of the fourth edition *PCI Bridge Design Manual* provides a detailed mathematical explanation of how prestress loss and beam concrete stresses due to shrinkage of deck concrete are accounted for in the AASHTO LRFD specifications and how these topics are treated differently in the fourth edition *PCI Bridge Design Manual*. This article summarizes the main points of that appendix. The reader is directed to the appendix of Chapter 8 of the fourth edition of the *PCI Bridge Design Manual* for a more thorough and detailed discussion.

Shrinkage of Deck Concrete: PCI Recommendation

When the concrete deck is composite with the prestressed concrete beam, the shrinkage deformation of the deck causes deformations throughout the composite cross section. Internal self-equilibrating forces in the prestressing reinforcement and concrete section are then developed.

The self-equilibrating internal forces associated with shrinkage of the deck concrete can be determined by performing an initial strain analysis. This analysis is similar to the procedure that would be carried out for temperature changes.

The initial strain analysis is accomplished with the following steps:

1. Remove the bond between the deck and beam concrete, allowing the deck to deform freely: ε_{ddf} in **Fig. 1**.
2. Restore compatibility by applying a restoring force P_{dsr} to the deck, which returns the deck strain to zero (**Fig. 2**). Note that under the sustained restraining force, the deck concrete undergoes creep, so it is the total creep and shrinkage strain that is brought to zero by the restoring force.
3. Restore the bond between the deck and beam concrete and restore equilibrium by applying an equal and opposite restoring force P_{ds} to the composite section using the age-adjusted modulus of elasticity (**Fig. 3**).

This analysis results in a change in the stresses in the concrete section and a gain in the stress of the prestressing strand. Use of the age-adjusted modulus of elasticity in step 3 accounts for both the initial strain

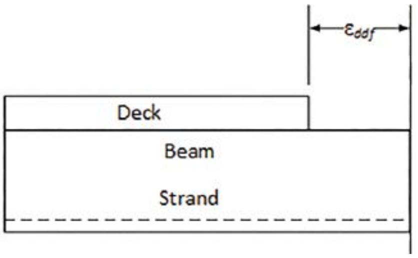


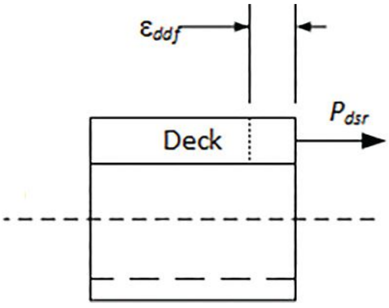
Figure 1. For step 1 of the initial strain analysis, the bond between deck and beam concrete is removed, allowing the deck to deform freely. All Figures: Washington State Department of Transportation.

caused by the internal self-equilibrating force in the net composite concrete section and the creep strain in the concrete that occurs over time due to the internal force developed in the net concrete section.

Treatment of Deck Shrinkage in the AASHTO LRFD Specifications

The prestress gain due to shrinkage of deck concrete Δf_{pSS} (LRFD Eq. 5.9.3.4.3d-1) in the time-dependent losses equation (LRFD Eq. 5.9.3.4.1-1) from the AASHTO LRFD specifications is obtained directly from the initial strain analysis. However, the change in beam concrete stress is not directly accounted for in the AASHTO LRFD specifications and is often overlooked. Treating the shrinkage of deck concrete as an external force is a simple method of estimating the effect shrinkage of the deck concrete has on the beam section. When the beam concrete stress is computed using transformed sections,

Figure 2. In step 2 of the initial strain analysis, deck concrete strain is restored to zero by applying force P_{dsr}.



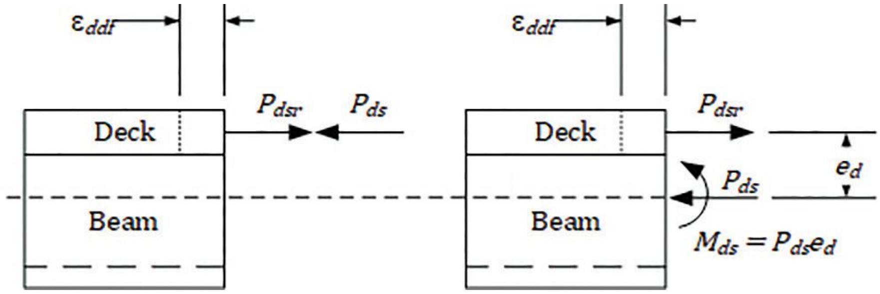


Figure 3. In step 3 of the initial strain analysis, equilibrium is restored by applying an equal and opposite restoring force P_{ds} to the composite section using the age-adjusted modulus of elasticity.

the effect of bond and strain compatibility between the prestressing steel and concrete is implicitly considered; hence this effect is called the "implicit elastic gain." For deck shrinkage, the implicit elastic gain is directly included in Δf_{pSS}. When using transformed section analysis, the implicit elastic gain due to shrinkage of the deck concrete is accounted for twice: once in Δf_{pSS} and once in the transformed section stress analysis.

Excluding Δf_{pSS} from the time-dependent prestress losses corrects a double-counting issue when transformed section analysis is used. However, Δf_{pSS} also includes the change in prestress due to beam concrete creep induced by the tension stress in the beam from deck shrinkage. These creep strains elongate the strand, resulting in an increase in the effective prestress and a change in the beam concrete stress. Excluding Δf_{pSS} eliminates this effect from the stress analysis; however, the effect can be captured by computing the beam concrete stress using age-adjusted composite transformed area and section modulus. Because this contribution to the overall beam concrete stress is small, nontransformed section properties may be used without appreciable loss of accuracy.

Conclusion

PCI recommends that the prestress gain caused by deck shrinkage Δf_{pSS} be excluded in the calculation of time-dependent prestress losses because the calculated magnitude of deck shrinkage strains may not develop in the presence of deck cracking and deck reinforcement. The gain in prestress due to deck shrinkage modeled in Δf_{pSS} accounts for both elastic and beam concrete creep-induced elongation of the strand. When transformed section analysis is used, the elastic gain is incorrectly accounted for twice. Excluding Δf_{pSS} corrects this issue but excludes the effect of beam concrete creep induced by the shrinkage of deck concrete.

PCI also recommends that the effect of deck shrinkage should be analyzed by considering it as an external force applied to the nontransformed composite section. This force is applied at the center of the deck with an eccentricity from the center of the deck to the center of gravity of the composite section.

This approach to computing stresses in the beam concrete is used for the design examples presented in Chapter 9 of the forthcoming fourth edition *PCI Bridge Design Manual*.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020 *AASHTO LRFD Bridge Design Specifications.* 9th ed. Washington, DC: AASHTO.
2. Precast/Prestressed Concrete Institute (PCI). Forthcoming. *Bridge Design Manual*. MNL-133. 4th ed. Chicago, IL: PCI.

CONCRETE BRIDGE TECHNOLOGY

Building a Park over an Interstate

Pittsburgh's Interstate 579 Urban Open Space Cap Project

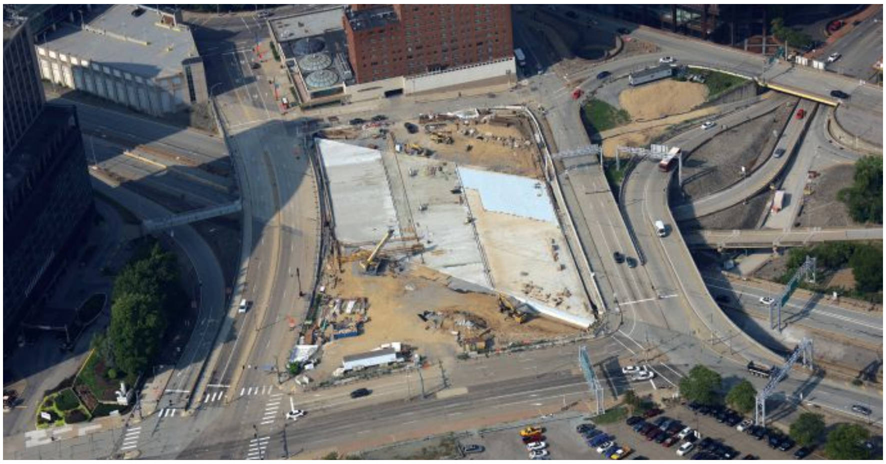
by Kyle Smith, Nick Burdette, and Roger Eaton, HDR Inc.

The Interstate 579 (I-579) Urban Open Space Cap project in Pittsburgh, Pa., reconnects the city's historic Hill District with the downtown business and cultural center. Completed in late 2021, this project literally capped (covered) about 300 ft of I-579 and created a 3-acre park that features performance and green spaces, integrates local art, and includes an amphitheater.

The dense urban site and unique park loading for this new structure required an innovative design and construction expertise. There are no design codes for bridges carrying a park, so project-specific criteria were developed to meet the demands that will be placed on the structure.

The Sports & Exhibition Authority of Pittsburgh and Allegheny County acted as the lead design agency alongside the City of Pittsburgh as owner, with oversight from the Pennsylvania Department of Transportation (PennDOT) and review from the Federal Highway Administration. The lead designer for the $32 million project coordinated with federal, state, and local entities, as well as private and nonprofit organizations, to bring this successful project to fruition.

The site of the Interstate 579 Urban Open Space Cap project as construction begins, with the interstate highway running beneath. Photo: HDR Inc.



The Interstate 579 Urban Open Space Cap site in the middle stage of construction, with precast concrete box beams in place over the interstate highway. Photo: HDR Inc.

A New Connection

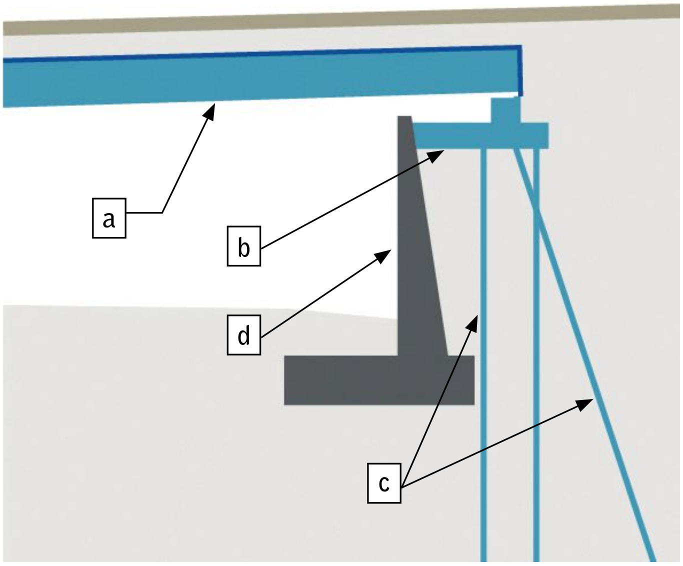
In the 1950s, as part of the construction of the former Civic Arena and other development activities, entire blocks of homes and businesses in Pittsburgh's Lower Hill neighborhood were demolished. During that time, Crosstown Boulevard was built, creating a "concrete canyon" of tall retaining walls and noisy highway traffic, essentially separating the Hill District from the downtown. In 1972, this highway became I-579. The Urban Open Space Cap project bridged this concrete canyon and created a tree-lined park over the highway, providing a walkable link to a neighborhood that had lost its direct access to downtown.

Project Overview

The new cap structure was constructed between two existing highway bridges that carry local traffic over I-579. The constrained construction site required special attention to minimize lane closures and avoid damaging existing structures. Micropile and drilled-shaft foundations were used to preserve the existing retaining walls along I-579.

Three new bridge units, composed of 126 prestressed concrete adjacent box beams, were placed between the existing crossings. The three units have different span lengths due to the geometry constraints and skew of the substructure units. Other features include redundant waterproofing systems and lightweight

The reinforcement cages for the pier columns are in place and formwork is being constructed. All mild reinforcement on the project is epoxy coated. Photo: Pennsylvania Department of Transportation.



Cross section of the cap structure. The prestressed concrete box-beams (a) are supported by semi-integral abutments (b) founded on micropiles (c). Micropiles were used to preserve the existing retaining walls (d) along Interstate 579. Figure: HDR Inc.

expanded polystyrene geofoam blocks to limit fill weight.

Substructure Design and Construction

The cap structure is supported by semi-integral abutments founded on more than 200 drilled micropiles, which were selected to minimize vibration and enable the use of a smaller drilling rig—an advantage in the limited space behind existing retaining walls.

The piles are offset from the existing retaining wall footings to avoid drilling through the heel. The battered piles are angled backward from the existing retaining walls and resist the lateral loads from the cap structure in tension, rather than in compression as is typical for battered piles.

Lightweight expanded polystyrene geofoam blocks are cut to fit and used as fill material to reduce soil loading on the bridge structures. Photo: HDR Inc.

The piers supporting the cap structure consist of four multicolumn pier bents founded on drilled caissons socketed into sandstone bedrock. Construction of the 42 drilled caissons took place in the gore areas approximately 30 ft below the interstate roadway. The proposed foundations were carefully evaluated to ensure that the necessary work area would be provided and the impact on interstate traffic would be minimized. Where possible, the caissons have a diameter of 3 ft 6 in., but caissons in some locations required a diameter of 3 ft 0 in. to avoid interference with existing retaining wall foundations.

Superstructure Design and Construction

The superstructure supporting the park and backfill consists of standard 48-in.-wide, 66-in.-deep PennDOT prestressed concrete adjacent box beams made continuous for composite dead and live loads. The superstructure is divided into two two-span units and one three-span unit. Separating the beams into three units allowed installation of transverse post-tensioning and permitted slight differential deflection between the units. The location of the piers matches the adjacent roadway bridges. The structure required 126 beams. Because the supports are nonparallel and skewed, the span lengths of the beams range from approximately 54 to 120 ft. The number of special (0.52-in.-diameter) strands varies by unit and ranges from 24 strands per beam for the shortest spans to 72 for the longest.

At each edge of the cap structure, a deck wall retains the backfill for the park.

After evaluation of several possible beam types, precast concrete adjacent box beams were selected for several reasons:

- The precast concrete elements were economical, but also strong enough to support the unique park loading, including up to 5 ft of soil and pedestrian or stage loading.
- Given the structure's location over an interstate highway, minimizing future maintenance was a high priority. Precast concrete beams do not need to be painted and, with an expected 100-year service life, they will withstand the test of time, reducing long-term costs.
- The beams provided a smooth soffit that contributes to aesthetics under the bridge and provides a consistent surface to attach the lighting system.
- The inherent fire resistance of precast concrete beams is an asset for this wide bridge overpassing an interstate highway.

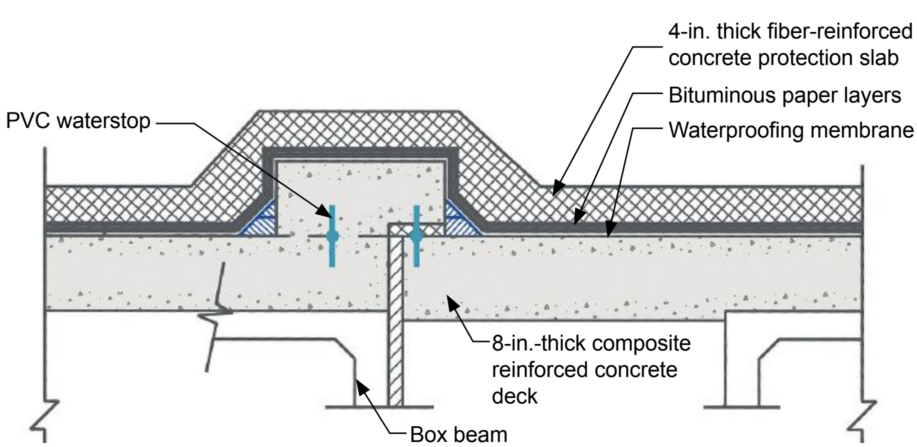
The top "event lawn" portion of the park was designed with a special soil mixture capable of absorbing up to 6 in. of water in a rain event. The minimum thickness of the soil on the cap was about 2 ft; however, the varied park topography meant that the soil depth in some areas would be about 5 ft, adding significant dead load to the bridge beams. To reduce the dead load from soil, expanded polystyrene geofoam blocks were buried in the deepest portion of the park. These blocks weigh 3 lb/ft^3 and satisfy project requirements for resistance to freezing and thawing, buoyancy (when the soil becomes saturated), and compression strength for truck-tire loading.

Determining the design loading for the structure was a unique challenge. The

The finished park on top of the Interstate 579 Urban Open Space Cap reconnects neighborhoods with downtown Pittsburgh, Pa., after being cut off since the 1950s. Photo: HDR Inc.

Some of the precast concrete adjacent box beams have been erected for three new bridge units between two existing bridges over Interstate 579. Photo: Pennsylvania Department of Transportation.

dead loads consist of the self weight of the superstructure and deck, protection slab, earth load, event platform load (not combined with vehicular live load), and a load for utilities attached to the underside of the box beams. Two live-load scenarios were considered when designing the beams. The first scenario considered the standard load-rating vehicles used to determine bridge posting in Pennsylvania (H20, HS20, ML80, and TK527), which approximated the vehicle loading that would be present when construction and maintenance vehicles access the park in the future. The second scenario considered the pedestrian loading that would be present in the final condition. Because the park will be used to host events and concerts, the 150 lb/ft^2 stage assembly area live load from the American Society of Civil Engineers' *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*[1] was used. Both live-load scenarios were considered concurrently with the worst-case dead and earth loads. The vehicular live-load scenario generally controlled the design of each beam.



Cross section of the structure where two units meet at a raised curb, showing the waterstop detail, waterproofing, drainage, and protection layers. Figure: HDR Inc.

After the box beams were erected and transversely post-tensioned, a traditional 8-in.-thick composite reinforced concrete deck was placed on top of the beams. A redundant waterproofing and drainage system was then installed to protect the structure from deterioration and prevent ice from forming and falling onto I-579. The system includes waterstops between structure units, layers of bituminous paper and waterproofing membrane on the top of the superstructure and back face of the semi-integral abutments, a 4-in.-thick fiber-reinforced-concrete protection slab to prevent damage to the waterproofing from future excavation, and a continuous aggregate drainage layer across the sloping superstructure.

"A Time to Celebrate"

For more than six decades, Pittsburgh's Hill District was isolated from the downtown by I-579 and a sea of parking lots. The new Frankie Pace Park, built on a structure that required design innovation, technical expertise, and dedication to the community, has changed that.

"This is really a time to celebrate," said Pennsylvania Governor Tom Wolf at the ribbon-cutting ceremony for the park in November 2021. "A great injustice was done in the '50s, and this is finally, at long last, a way to address that injustice."

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Pilot Project Using Electrically Isolated Tendon Post-Tensioning System and Grout Sensors

by Jordan Sessa and Dr. Zuming Xia, Structural Technologies, and Jean-Baptiste Domage and Adrian Gnagi, VSL International

The State Highway 146 (SH 146) bridge bent 107 in Kemah, Tex., was selected as a Federal Highway Administration (FHWA) pilot project for an electrically isolated tendon (EIT) application, with the Texas Department of Transportation as cosponsor. Fully encapsulated post-tensioning (PT) tendons or protection level 2 (PL2) tendons provide enhanced durability performance. However, in current PT practice in the United States, it is not possible to remotely monitor the in-service condition of tendons. PT systems using EITs, or protection level 3 (PL3) tendons, provide a high level of corrosion protection and the ability to monitor PT tendon condition throughout a structure's life cycle.[1]

Technology on the SH 146 project included vacuum-assisted grouting and structural health–monitoring sensors, which were used as quality-control measurement tools during and after the grouting process. The proprietary sensors used on this project collect data while the grout is still in its fluid state to verify whether the grouting operation is complete or if a secondary injection is required. The use of the sensors eliminates the need to drill behind the anchor or bearing plate during a post-grout inspection, which is the current PT practice and can potentially compromise EIT performance.[2]

To interpret data from the proprietary grout sensors during grout placement, normal ranges for the prepackaged grout are established by mixing grout at the correct water-cement (*w/c*) ratio and at an excessive *w/c* ratio. All Photos and Figures: Structural Technologies/VSL International.

EITs were initially developed for structures with DC voltage power, such as light-rail transit. In such structures, the stray current from the electrical source can cause accelerated corrosion in the steel components of the concrete structure, including the PT strands, with serious consequences to the integrity of the structure. Stray current is not only able to travel through mild reinforcement; it can also travel through cementitious material such as concrete and grout to find its way to the PT strand. Therefore, EITs require not only complete encapsulation around the tendon envelope, but also complete electrical isolation of the PT strand from the environment outside the tendon envelope.

EIT technology has been deployed in Switzerland since the 1990s and bridge owners have found that, in addition to protecting from stray current, the system provides assurance that the PT system has been installed according to the system design.[3] As a result, the owner can have greater confidence in the quality of the PT system integrity. In addition, corrosion-inducing materials cannot penetrate the tendon without being immediately detected by the EIT system, even before corrosion occurs. On the SH 146 project, this high level of confidence was achieved by using nonconductive PT materials from end-to-end, and includes:

- permanent plastic grout caps,
- a seamless extruded plastic duct,
- a plastic trumpet that extends from the wedge plate to the duct, rather than only from the end of the bearing plate, and
- high-strength, nonconductive material that isolates the wedge plate and bearing plate.

The first two items (plastic grout caps and plastic duct) are standard for PL2 tendons. The plastic trumpet must prevent contact between the strand and the bearing plate and may require some modification to existing PT system designs or an upgrade of the anchorage plate size. The plastic trumpet is the only new piece of hardware required to upgrade a PL2 tendon to PL3. Thus, existing PT systems can be upgraded to meet the PL3 requirements with only minor modifications to the existing hardware components.

In addition to achieving electrical isolation, the PL3 standard requires the ability to monitor the tendon for electrical isolation during and after construction by nondestructive means. Monitoring is achieved by checking the electrical resistance between the PT strand and the reinforcing steel with an LCR meter. (An LCR meter is used to measure the inductance, capacitance, and resistance of a component.) The LCR meter is used to measure the impedance of the system because the tendon includes both grout (resistive material) and a plastic duct (capacitive material); therefore, a static resistance

For the pilot project, the junction box for the electrically isolated tendons was placed at a readily accessible location at ground level. The electrically isolated post-tensioning system connection to each anchorage is blue.

measurement is not appropriate. If the tendon is electrically isolated, the resistance (ohms) of the grout does not reduce the measured impedance and the reading will be controlled by the resistance of the plastic duct, which is relatively high. For a continuous construction system, if the specific resistance is measured at a sufficiently high value (50 kΩ-m for each tendon), then an effective EIT has been created. A copper lead (12-gauge insulated wire) is attached to the reinforcing steel before concrete placement (ground wire), and another lead is attached to the strand or wedge plate. These wires are routed to a junction box that is readily accessible on the structure. An LCR meter is used to measure the resistance at 1 kHz. Electrical leakage can be found in a variety of measurements, such as the following:

- Very low resistance indicates a short circuit has occurred between the strand and reinforcing steel. The likely cause of a short circuit is direct steel-to-steel contact from a breakage in the tendon envelope or moisture leaking through the duct-trumpet connections and bridging the contact.
- Moderate resistance indicates that an electrical leakage has occurred by infiltration of grout, cement paste, or both through the duct connections, or by the plastic duct being compromised due to incorrect installation that caused a kink or dent in the duct on one of the reinforcing support bars.

Electrically isolated tendons after tensioning. The electrical isolation plate underneath the wedge plate creates isolation between the strands and the bearing plate.

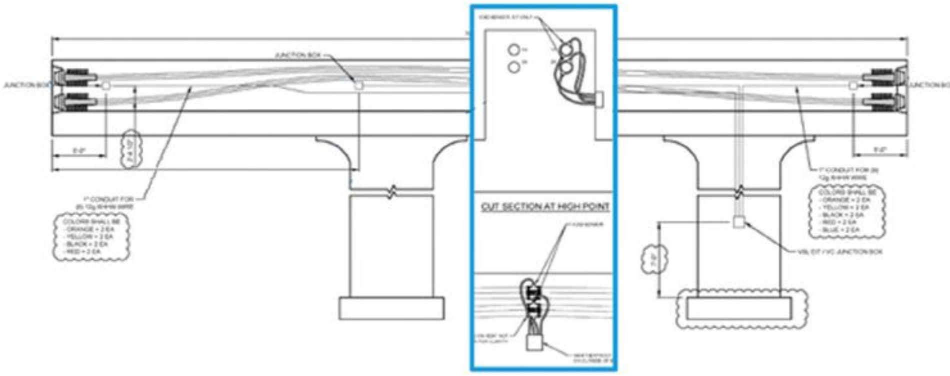
Tendon monitoring occurs at multiple stages during construction. At a minimum, it should occur at the following points:

1. After strand is installed, but before tensioning. An electrical leak at this stage indicates a severe break in the tendon envelope. This can be remedied by removing the strand, locating the break, and, if the break is in the duct, repairing it with pipe sleeve installed using an epoxy adhesive.
2. After tensioning. An electrical leak indicates a kink in the duct on the reinforcing steel. The act of tensioning causes the strand to wear through or compress the plastic to an insufficient thickness to act as an electrical barrier. This condition can be remedied if deemed necessary.
3. During and after grouting. Electrical isolation is expected to dramatically, but temporarily, decrease during grouting due to the conductivity of wet grout. As the grout cures, a logarithmic curve describing electrical isolation is expected, and electrical isolation is expected to return by 28 days.

The SH 146 project was constructed from November 2021 to May 2022 and included 20 PT straddle bent caps with cantilevered ends. The PT profile required the use of high-point grout vents. Because every grout vent creates an opportunity for electrical leakage, the final grouting plan called for removing the high-point vents and using a vacuum-assisted grouting method. This method eliminates the possibility of introducing air throughout the tendon before grouting and prevents voids in the tendon grout without the need to vent the air at the intermediate location.

Current post-grout inspection practices include drilling into the duct and trumpet for void inspection. Proprietary sensors were incorporated into the EITs on the SH 146 project to facilitate nondestructive testing. These sensors are placed at the top and bottom of the duct and anchorage. Using software, an electrochemical measurement based on the potential/pH diagram is taken to determine whether the tendon is full of grout at the location of the sensors. Through calibration, the data collected by the sensors allow the user to distinguish between well-mixed grout, watery grout, water, or a void. The sensors provide immediate feedback during the grouting process. Should an abnormal reading be found, additional grout can be pumped into the tendon to displace the defect and completely fill the tendon with high-quality grout.

A project like SH 146 does not require the use of EITs. In fact, very few PT projects have stray current concerns. However, one of the additional benefits of using a PL3 system is that the system provides the enhanced workmanship and quality control that are required to demonstrate electrical isolation. Rather than demonstrating the effectiveness of the PT system through one-time system testing and mock-ups, PL3 tendons require proof of electrical isolation for every installed tendon. With the addition of the proprietary sensors on this project, proof of quality grout filling for each tendon was also verified with nondestructive



Schematic diagram of electrically isolated tendons and sensors on State Highway 146 bridge bent 107 in Kemah, Tex. Sensors were put at the ends and the high point of each tendon.

testing. Vacuum-assisted grouting further enhances the workmanship, with all connections being completely airtight to achieve the vacuum required. After the completion of the project, the EITs can be easily checked on a regular basis for any undesirable changes in the tendon's electrical isolation. A sudden drop in isolation would indicate that the tendon envelope has been compromised and the tendon may be susceptible to corrosion. Proactive measures can then be taken to investigate and correct these defects before the tendon is beyond repair.

The FHWA EIT pilot project on SH 146 was a success. The EITs successfully met the electrical isolation requirements, and the sensors confirmed that the tendons were filled with grout. Based on this success, it is hoped that these two technologies will receive wider acceptance and implementation on future projects in the United States.

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CBEI SERIES

Bridge Deck Construction Inspection Program at the Concrete Bridge Engineering Institute

by Dr. Oguzhan Bayrak, Dennis Fillip, Gregory Hunsicker, Dulce Maria Trejo, and Zach Webb, Concrete Bridge Engineering Institute

A series of articles in previous issues of *ASPIRE*® introduced the Concrete Bridge Engineering Institute (CBEI) and presented two of its "pillars of learning," the Concrete Materials for Bridges Program and the Post-Tensioning Laboratory (PT Laboratory). Those articles also presented CBEI's collaborative efforts with the National Concrete Bridge Council. This article describes the Bridge Deck Construction Inspection Program along with an update on the Transportation Pooled Fund (TPF).

Program Scope

The Bridge Deck Construction Inspection Program is projected to open in the first half of 2024 and will offer training and certification programs. Support services for the program will also be offered through the concrete solutions center at CBEI, which will engage CBEI staff and other subject matter experts to provide direct technical support, webinars, and custom workshops. Like other CBEI programs, the Bridge Deck Construction Inspection Program will serve as a hub for sharing information, standardizing procedures, and facilitating the implementation of new bridge deck technologies.

Program Goal

According to studies through the National Cooperative Highway Research Program,[1] concrete bridge deck deterioration is one of the leading causes of bridges being rated in poor condition. The deterioration of a bridge deck—for example, delamination, spalling, ponding, cracking, or corrosion—hinders the performance of the bridge and its components. Therefore, the manner in which a bridge deck is constructed is important to the bridge's efficiency, serviceability, and long-term performance. While the causes of bridge deck deterioration have been well researched and identified, individuals working in our industry require resources that provide field guidance on the construction and inspection deficiencies that lead to deterioration so they can recognize and prevent problems. The goal of the Bridge Deck Construction Inspection Program is to serve as a center for prevalent and emerging bridge deck construction techniques to the bridge industry, specifically for students, engineers, construction crews, bridge owners, and inspectors. The program will use full-scale bridge components to train participants on the proper construction of concrete bridge decks (**Fig. 1**).

Training Specimen Setup

One of the priorities of the Bridge Deck Construction Inspection Program is to provide hands-on training. To meet this goal, a three-span concrete bridge consisting of four girder lines will be constructed at the Ferguson Structural Engineering Laboratory in Austin, Texas. Each span will detail different phases of construction, specifically, prepour activities such as elevation control, forming, reinforcement placement, and dry-run setup. In addition, the concrete bridge deck training specimen will have built-in examples of deficiencies alongside best-practice installations. These deficiencies will include typical issues that engineers, contractors, and inspectors should be aware of, such as inadequate formwork placement, lack of reinforcement details, insufficient concrete consolidation, and more. **Figure 2** shows a preliminary rendering of the bridge deck training specimen.

Curriculum Development

The Bridge Deck Construction Inspection Program is intended to be a four-day program consisting of a series of modules focused on the design and construction of concrete bridge decks. The modules will address critical details from an inspector's perspective in the construction of a bridge deck, such as adequately placing reinforcement; setting up and operating a screed; performing a screed dry run; placing, curing, and finishing concrete; and other crucial details such as formwork, joints, and precast concrete deck components. The course and training specimen will include information on various forming methods, including partial-depth precast concrete deck panels, stay-in-place metal deck forms, and wood forms (**Fig. 3**). Like the PT Laboratory, the modules are designed to be either taken individually or grouped together in custom blocks; the modules will also complement existing

Figure 1. Rendering of the full-scale bridge deck construction mock-up to be used in the Concrete Bridge Engineering Institute's Bridge Deck Construction Inspection Program. All Figures and Photos: Concrete Bridge Engineering Institute.

Figure 2. Participants in the Bridge Deck Construction Inspection Program will learn about deficiencies and results of deficiencies through a full-scale specimen of a bridge deck under construction similar to the one shown in this rendering.

Figure 3. The full-scale training specimen at the Concrete Bridge Engineering Institute will incorporate various forming methods, including partial-depth precast concrete deck panels, stay-in-place metal deck forms, and wood forms.

courses and avoid redundancy. As new procedures, materials, and technologies are introduced to the industry, modules will be updated or new modules will be created as needed. For example, the course intends to incorporate different reinforcement types including both bare and epoxy-coated reinforcing steel. Procedures for inspection and proper repair of epoxy coating are some of the topics to be included.

A sampling of the training modules includes:

- Overview/Introduction/Detailing
- Materials and Components
- Reinforcement
- Geometry Control, Elevations, and Tolerances
- Concrete Placement
- Post-Deck Placement

Research and New Technologies

As previously mentioned, the Bridge Deck Construction Inspection Program aims to incorporate new procedures, materials, and technologies into its training modules as they are introduced to the industry. To do so, the program curriculum will closely follow the development of industry best practices and research in deck construction. One example of an industry best practice that the program intends to incorporate is the Federal Highway Administration's *State-of-the-Practice Report: Partial-Depth Precast Concrete Deck Panels*,[2] published in June 2022. The report discusses design, fabrication, and installation practices of partial-depth precast concrete deck panels, which provide advantages in the design and construction of bridge decks. The NextGen Texas Bridge Deck research project underway at the University of Texas at Austin is an example of current research on bridge decks that will also be incorporated into the Bridge Deck Construction Inspection Program. This research project includes the testing of full-scale specimens and aims to develop design guidelines for full-bridge-width, partial-depth precast concrete deck panels (**Fig. 4**). The program also aims to incorporate nondestructive evaluation techniques and draw from the best and most current state-of-the-art methods.

Transportation Pooled Fund Update

TPF 1580, the Concrete Bridge Engineering Institute, recently reached and exceeded its commitment requirements and has been officially launched. Information on the initiation of the solicitation was presented in the Fall 2022 issue of *ASPIRE*. Many thanks and much appreciation go to the members of the CBEI TPF: the Texas Department of Transportation (Lead Agency), Federal Highway Administration, Colorado Department of Transportation, Georgia Department of Transportation, Iowa Department of Transportation, Michigan Department of Transportation, Minnesota Department of Transportation, Pennsylvania Department of Transportation, and Utah Department of Transportation. Initial groundwork is already underway and additional site preparation and specimen installation are anticipated to commence in the near future. The CBEI staff looks forward to an upcoming kickoff meeting among the representatives of the TPF at an initial Technical Advisory Committee meeting.

Conclusion

This article is the fifth in a series of articles about CBEI and its impact on the construction industry. For more information about CBEI, please visit www.cbei.engr.utexas.edu.

Figure 4. The NextGen bridge deck research project, which is being conducted at University of Texas at Austin, is studying partial-depth precast concrete deck panels. Results of this research project, as well as other projects involving bridge deck construction, will be incorporated into the Bridge Deck Construction Inspection Program.

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Details on Two Changes to the Ninth Edition *AASHTO LRFD Bridge Design Specifications*

by Dr. Oguzhan Bayrak, University of Texas at Austin

This article focuses on the final two working agenda items that were approved by the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures during their June 2022 meeting for inclusion in the forthcoming 10th edition of the *AASHTO LRFD Bridge Design Specifications*.[1]

Lightweight Concrete Clarifications

The provisions of Section 5 of the AASHTO LRFD specifications[2] are based on design concrete compressive strengths varying from 2.4 to 10.0 ksi for normalweight and lightweight concrete, except where higher strength, not exceeding 15.0 ksi, is allowed for normalweight concrete. To that end, Appendix C5 will be revised to provide clear guidance on the upper limits of compressive strength for normalweight concrete (**Table 1**). Noteworthy changes include that the upper limit of compressive strength that governs Articles 5.10.8.2.5 (welded wire reinforcement) and 5.10.8.2.6 (shear reinforcement) have been revised up to 15 ksi and hoops have been added to Article 5.6.4.6.

In the 9th edition of the AASHTO LRFD specifications, the exceptions for higher-strength normalweight concrete are given in the specific articles. However, the language used to describe the exceptions can be misconstrued and taken to mean that the section is only applicable to normalweight concrete. Additionally, some sections provide extra requirements for lightweight concrete, which are unnecessary.

The revisions will clarify the intent of the specifications and put lightweight concrete on the same plane as normalweight concrete. To that end, Table 5.12.5.3.3-1 (**Table 2**) will be revised, and the lightweight concrete factor λ will be added to the stress limits section. In all, 40 items will be revised within this working agenda item pertaining to lightweight concrete to ensure that the lower tensile strength of lightweight concrete is accounted for only once. Multiple penalties concurrently applied to tensile strength of lightweight concrete and behavioral modes that are governed by the tensile strength have been eliminated. This revision is consistent with the broader philosophy of structural safety and desired levels of target reliability factors in structural design that is inherent to the AASHTO LRFD specifications.

Concrete Anchors

In 2019, the American Concrete Institute (ACI) modified the provisions

Table 1. Excerpt from Appendix C5, "Upper Limits of Normalweight Concrete for Articles Affected by Concrete Compressive Strength," showing revisions in the forthcoming *AASHTO LRFD Bridge Design Specifications*, 10th edition[1]

Article*	Upper limit,† ksi	
	10.0	15.0
5.6.4.6 Spirals, Hoops, and Ties		X
5.8.2.7 Application to the Design of General Zones of Post-Tensioning Anchorages		X
5.9.3 Prestress Losses		X
5.10.8.2.5 Welded Wire Reinforcement		X
5.10.8.2.6 Shear Reinforcement		X
5.11.3.2 Concrete Piles	X	
5.11.4.5 Concrete Piles	X	
5.12.5.3.8 Alternative Shear Design Procedure	X	
5.12.7 Culverts	X	

*Applies to all subarticles within the listed article.
†Article 5.1 establishes the upper limit for the specified design compressive strength of lightweight concrete as 10.0 ksi for all articles in Section 5.

Table 2. Revised Table 5.12.5.3.3-1—Load Factors and Tensile Stress Limits for Construction Load Combinations in the forthcoming *AASHTO LRFD Bridge Design Specifications*, 10th edition[1] (Notes are not shown.)

Load Combination	LOAD FACTORS															STRESS LIMITS				
	Dead Load			Live Load			Wind Load			Other Loads					Earth Loads	Flexural Tension		Principal Tension		
	DC *DW*	*DIFF*	*U*	*CEQ* *CLL*	*IE*	*CLE*	*WS*	*WUP*	*WE*	*CR*	*SH*	*TU*	*TG*	A AI *WA*	*EH* *EV* *ES*	Excluding "Other Loads"	Including "Other Loads"	Excluding "Other Loads"	Including "Other Loads"	See Note
a	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	—
b	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	—
c	1.0	1.0	0.0	0.0	0.0	0.0	0.7	0.7	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	—
d	1.0	1.0	0.0	1.0	0.0	0.0	0.7	1.0	0.7	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	1
e	1.0	0.0	1.0	1.0	1.0	0.0	0.3	0.0	0.3	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	2
f	1.0	0.0	0.0	1.0	1.0	1.0	0.3	0.0	0.3	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\lambda\sqrt{f'_c}$	$0.220\lambda\sqrt{f'_c}$	$0.110\lambda\sqrt{f'_c}$	$0.126\lambda\sqrt{f'_c}$	3

for concrete anchors in Chapter 17, "Anchoring to Concrete," and Chapter 26, "Construction Documents and Inspection," of the *Building Code Requirements for Structural Concrete* (ACI 318-19) *and Commentary* (ACI 318R-19).[3] A 2021 agenda item for the AASHTO LRFD specifications updated Article 5.13 to reflect those changes. This 2022 agenda item will make the next edition of the *AASHTO LRFD Bridge Construction Specifications*[4] consistent with the design provisions that were updated in 2021. This agenda item covers the installation and inspection of cast-in-place and post-installed anchors in concrete that are used to resist tension or shear, or a combination thereof, and designed in accordance with the applicable provisions of Article 5.13 of the AASHTO LRFD specifications, 10th edition (see Editor's Note). The anchor types covered in this specification include:

- headed studs, headed bolts, and hooked bolts,
- post-installed expansion (torque-controlled and displacement controlled) anchors that meet the assessment criteria of ACI CODE-355.2,[5]
- post-installed undercut anchors that meet the assessment criteria of ACI CODE-355.2,
- post-installed adhesive anchors meeting the assessment criteria of ACI CODE-355.4,[6] and
- post-installed screw anchors meeting the assessment criteria of ACI CODE-355.2.

The forthcoming revised construction specifications[4] include in-depth specification and commentary language to cover a broad range of issues. Section 29.2, "Materials and Pre-Qualification," gives important details on materials conformance requirements. Section 29 broadly references the manufacturer's printed installation instructions (MPII) and the use of MPIIs. Importantly, MPIIs are to include all information needed to properly install any post-installed anchors. The types and diameters of drill bits that may be used, cleaning instructions, mixing instructions, gel and cure times, set requirements, and other pertinent installation information are all covered in this section. This section also includes guidance and requirements on the prequalification process, working drawings, and submittal processes for post-installed anchors. Section 29.3 covers the installation and inspection processes. The revised Section 29.3.1 reads as follows:

> *Substitution of any anchor type for another anchor type shall not be permitted without the approval of the Designer.*
>
> *When using cast-in-place anchors, all anchors, their attachments, and anchor reinforcement shall be securely positioned in the formwork and oriented in accordance with the contract documents. Concrete shall be consolidated around the anchors and reinforcement in accordance with Article 8.7.4.*
>
> *For post-installed anchors, drill the hole to the appropriate depth as provided by the contract documents. The hole shall be drilled and cleaned with equipment and using a process in accordance with the MPII. Protect anchors intended for attachment with future work in a manner which will prevent the degradation of the anchor element or any permissible coatings.*
>
> *For adhesive anchors, ensure that the adhesive has a characteristic bond strength in cracked and uncracked concrete consistent with what is required in the contract documents. Adhesive shall be stored in a manner and at a temperature specified by the manufacturer. Adhesive anchors oriented in a horizontal or upwardly inclined orientation shall be installed by a certified ACI Adhesive Anchor Installer.*
>
> *(a) The Contractor shall furnish the ACI Registration Number of all Adhesive Anchor Installers working on the project a minimum of 30 days prior to installation.*
>
> *(b) All Adhesive Anchor Installers working on the project shall provide their ACI Certification Card in the field upon request by the Engineer or Owner.*
>
> *Adhesives shall be mixed in accordance with the MPII and shall not be disturbed after the manufacturer established gel time. Loads shall not be applied to adhesive anchors until the adhesive has completely cured. Adhesives shall be installed in concrete having a minimum age of 21 days at the time of anchor installation.*
>
> *Anchors shall be installed with a minimum edge distance of the anchor as established in the contract documents. The hole depth and diameter shall be verified to be consistent with the contract documents and the MPII prior to anchor installation.*
>
> *If there is a discrepancy between the contract documents and the*

MPII, resolve with the Designer and product manufacturer prior to drilling and installation.

Section 29.3.2 articulates that all inspections are to be performed by a certified inspector or a qualified inspector specifically approved for that purpose by the owner, and it provides additional details on important aspects of the inspection process. For example, adhesive anchors in a horizontal or upwardly inclined orientation or intended to hold sustained tension are to be continuously inspected during installation for compliance with the MPII and the contract documents. Other anchors and adhesive anchors are to be periodically inspected during installation for compliance with the MPII and the contract documents. This section also requires demonstration testing and production proof testing of post-installed anchors. Section 29.4 covers measurements, and Section 29.5 focuses on payments.

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EDITOR'S NOTE

ASPIRE® *featured a four-part series on concrete anchors and their incorporation into the* AASHTO LRFD Bridge Design Specifications. *The topic of each article, the* ASPIRE *issue in which it appeared, and the corresponding link are as follows:*

Part 1 appeared in the Summer 2020 issue of ASPIRE. *The article discussed results of the National Transportation Safety Board report outlining the failure of epoxy-adhesive anchors on Boston's Big Dig project in 2006 and the PCI program sponsored by the Transportation Research Board to educate bridge engineers on the implementation of the concrete anchorage provisions in the AASHTO LRFD specifications. https://www.aspirebridge.com/magazine/2020Summer/AASHTO-LRFD-AnchorsInConcrete.pdf*

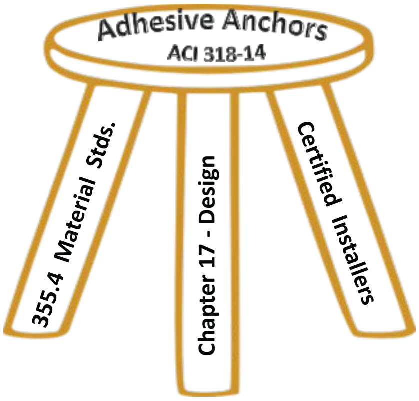
Part 2 appeared in the Fall 2020 issue of ASPIRE. *It discussed the qualification procedures that manufacturers must follow for testing and establishing design values for concrete anchors. (ACI CODE-355.2*, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary *and ACI CODE-355.4*, Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary*) https://www.aspirebridge.com/magazine/2020Fall/AASHTO-LRFD-AnchorsInConcrete.pdf*

Part 3 appeared in the Winter 2021 issue of ASPIRE. *The procurement of concrete anchors was discussed in this part of the series. Anchor design, materials, installation, installer certification, and inspection requirements to be indicated in contract documents were also covered. https://www.aspirebridge.com/magazine/2021Winter/LRFD-AnchorsInConcrete.pdf*

Part 4 appeared in the Spring 2021 issue of ASPIRE. *This article discussed the certification for anchor installers and inspectors, inspection requirements, and compliance testing of installed anchors. https://www.aspirebridge.com/magazine/2021Spring/AASHTOLRFD-AnchorsInConcrete.pdf*

Access to the PCI five-session webinar training series on concrete anchor design is available at PCI.org/AnchoringToConcreteImp

For each of the five webinars, the following are available to download: the PowerPoint slides used in the presentation, a video of the presentation, the text of the presentation, course resource documents, and a transcript of all the questions asked at the end of each webinar and the answers provided. These materials are available at no charge.



There are three legs to the adhesive anchor quality stool: design procedure, qualification protocol, and installer certification.

Concrete breakout failure of an anchor where the tension load strength has been influenced by the distance from the center of the anchor to the free edge of the member.

Lightweight Concrete: Improving Concrete Member Efficiency, Performance, and Durability

by Reggie Holt, Federal Highway Administration, and Dr. Reid Castrodale, Castrodale Engineering

Lightweight concrete is not a new material, although many engineers may not be familiar with it. It has been used successfully for the construction of bridges since soon after commercial production of lightweight aggregate began in the United States over 100 years ago.[1] The American Association of State Highway and Transportation Officials' (AASHTO) bridge design specifications have included some mention of lightweight concrete since at least 1969, and provisions similar to those in the eighth edition *AASHTO LRFD Bridge Design Specifications*[2] have been present since 1983. A comprehensive report on the use of lightweight concrete for prestressed concrete members was developed in 1966 by the International Federation for Prestressing Commission on Prestressed Lightweight Concrete.[3] In 1985, the Federal Highway Administration (FHWA) published *Criteria for Designing Lightweight Concrete Bridges*.[4] That report stated that lightweight concrete has a "sufficient record of successful applications to make it a suitable construction material … for bridges" and "sufficient information is available on all aspects of its performance for design and construction purposes."

Benefits of Lightweight Concrete

An obvious reason for using lightweight concrete in bridges is the reduced unit weight of the concrete, which leads to a reduction in member self weights that are supported by a structure. That can improve design efficiency in several ways,[5] including the following:

- Allowing for extended span ranges, wider girder spacings, or shallower girder sections
- Decreasing design loads on bearings, substructure elements, and foundations
- Reducing the weight of precast concrete components for handling, transportation, and erection

A second benefit is less obvious and perhaps counterintuitive: enhanced durability. While it might seem likely that using a porous aggregate would reduce the durability of concrete, and therefore the expected service life of a bridge, field and laboratory experience have shown that lightweight concrete has equal or improved durability compared with normalweight concrete with the same compressive strength.[6–9] Reasons for the enhanced durability of lightweight concrete include the following:

- Internal curing from prewetted lightweight aggregate, which reduces shrinkage, cracking, and permeability
- Elastic compatibility due to the similar stiffness of aggregate and paste, which reduces internal microcracking and also reduces permeability
- Lower modulus of elasticity, which tends to reduce cracking
- Lower coefficient of thermal expansion, which also tends to reduce cracking

In recent years, the concept of internal curing, in which prewetted lightweight aggregate is substituted for a portion of the conventional sand in an otherwise conventional concrete mixture, has increasingly become recognized as an effective approach to improve durability of concrete.[10–12] In this way, internal curing uses prewetted lightweight aggregate to deliver curing water to the interior of concrete rather than using the aggregate to reduce density.

Reasons to Use Lightweight Concrete

Lightweight concrete has been used in bridges for many reasons; most are related to the reduction in the weight of the structure and the associated improvements in efficiency. As noted previously, durability and extended service life are also recognized as significant benefits of lightweight concrete.[6,13] While this discussion divides reduced weight and enhanced durability into separate topics, the topics are often interrelated.

Reduced Weight or Load

Typically, the main benefit of using lightweight concrete is the reduction of the weight of the structure or an element that results in improved design efficiencies and reduced costs for girders, substructures, and foundations. This reduced weight or load allows for improved design efficiency, increased span lengths, improved seismic performance, lower member handling and hauling loads, and reduced substructure/foundation loads with possible reuse of substructures for bridge replacements.

Enhanced Durability

Using lightweight aggregate in concrete for a bridge can lead to improved durability. The durability of lightweight concrete may be comparable or even improved over normalweight concrete with the same compressive strength and similar mixture proportions.

The properties of lightweight aggregate and lightweight concrete related to durability include reduced permeability, reduced cracking, and good resistance to freezing and thawing. It is also anticipated that using lightweight concrete for mass concrete applications will reduce the cracking potential in members.[14,15]

The reduced coefficient of thermal expansion of lightweight concrete is expected to reduce thermal movements in bridges, which can extend the life of bridge joints and bearings, which are often maintenance problems. In some cases where there is a risk that deck restraint from girders could lead to early-age cracking, the reduced stiffness of lightweight concrete can be beneficial. For the same reason, if the columns were constructed using lightweight concrete, the restraint from short columns on the superstructure would be lessened.

Next Steps

While lightweight concrete has been successfully used for bridge projects for over 80 years, and design provisions for lightweight concrete have been provided in AASHTO specifications for many years, the material is not commonly used for bridge construction. In some cases, owners, designers, contractors, and others may assume that lightweight concrete is not a reasonable option for bridges. Another potential obstacle to the use of lightweight concrete is the perceived higher cost of the material. However, when evaluating the cost of using lightweight concrete for a project, long-term costs related to durability and service life should be considered, as well as initial costs. **Tables 1** and **2** list several bridge projects where lightweight concrete has been used. Finally, designers may be unsure about how to select properties of lightweight concrete for design, and how to perform design calculations.

To address these knowledge gaps, the Federal Highway Administration developed the *Light-*

Table 1. Projects where lightweight concrete was used to allow reuse of existing structural members

Project name (state)	Lightweight concrete application*	Specified unit weight, kcf	Design compressive strength, ksi	Year built
Interstate 895 Bridge over the Patapsco River Flats (MD)	Deck panels	0.100	4.5	2019
Shasta Arch Bridge on Southbound Interstate 5 (CA)	PS girders and bent caps	0.120	5.5	2018
Route 198 (Dutton Road) Bridge over Harper Creek (VA)	PS girders, deck, and railings	0.105 to 0.115	4.0 to 5.0	2016
Interstate 5 Bridge over the Skagit River (WA)	PS girders, diaphragms, and railings	0.122	4.0 to 9.0	2013
Beach Bridge – North Haven (ME)	PS girders	0.120	6.0	2013
Ben Sawyer Bridge – Sullivan's Island (SC)	Deck	0.115	5.0	2010
Massaponax Church Road Bridge over Interstate 95 (VA)	Deck and railing	0.120	4.0	2009
Brooklyn Bridge over the East River (NY)	Deck panels	0.118	3.6	1999
Coleman Bridge over the York River (VA)	Deck	0.115	5.0	1983
Woodrow Wilson Bridge over the Potomac River (DC)	PS deck panels	0.115	5.0	1983

Source: Data are from reference 16.

* Elements listed in this column are reinforced concrete, except for those noted as being prestressed concrete (PS).

Table 2. Projects where lightweight concrete was used to improve the structural efficiency of the bridge

Project name (state)	Lightweight concrete application*	Specified unit weight, kcf	Design compressive strength, ksi	Year built
Marc Basnight Bridge over the Oregon Inlet (NC)	Deck on approach spans	0.120	4.5	2019
Pulaski Skyway Bridge Rehabilitation (NJ)	Deck panels	0.120	6.0	2018
Benicia-Martinez Bridge (CA)	Cast-in-place segmental PS box girder	0.125	6.5	2007
Route 33 Bridges over the Mattaponi and Pamunkey Rivers (VA)	PS girders and PS spliced girders	0.125	8.0	2007
	Deck	0.120	5.0	
Francis Scott Key Bridge (MD)	Deck	0.112	4.0	1977
San Francisco–Oakland Bay Bridge (CA)	Deck	0.095	Unspecified	1961

Source: Data are from reference 16.

* Elements listed in this column are reinforced concrete, except for those noted as being prestressed concrete (PS).

weight Concrete Bridge Design Primer,[16] which was published in 2021 and can be downloaded from https://www.fhwa.dot.gov/bridge/concrete/hif19067_Nov2021.pdf. This document offers basic information relating to lightweight concrete so owners, designers, specifiers, and contractors can be equipped to properly evaluate the potential benefits of using lightweight concrete. Featuring laboratory data, information from field experience, and references, it demonstrates that lightweight concrete can be durable and cost effective for bridge designs and can reduce member weight for shipping and handling.

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Suzanne Aultman

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Suzanne Aultman has worked at Metromont for nearly 20 years, where she manages standards and codes, research and development, sales engineering, engineering training, and provides oversight for the day-to-day engineering operations. She earned her BS and MS in Civil Engineering from Clemson University, and she is a licensed professional engineer in 20 states. She is active in PCI, serving on the Technical Activities Council, the R&D Council, chairing the Standards Committee, Design Standard Committee, Blast and Structural Integrity Committee, PCI Academy Advisory Board, and the Industry Handbook Committee.

She is active in ACI as a member and past chair of ACI 550 Precast Structures, a member of ACI 319 Precast Structural Concrete Code, ACI 318-P Precast & Prestressed Concrete, and ACI 362 Parking Structures committee. She is also a member of ASCE and was a judge of the National Concrete Canoe Competition in 2015. She is a member of NSPE, SCSPE, and the Piedmont Chapter of SCSPE.

Corey Greika

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With 25 years in the precast, prestressed concrete industry, Corey Greika has held positions of QC technician, plant engineer, design engineer, engineering manager, sales engineer, and sales manager. He graduated from the Georgia Institute of Technology with a Bachelors of Civil Engineering (Structural) and a Bachelors of Science in Architecture. He has worked in the precast concrete industry in the Midwest and Southeast markets.

He is Vice Chair of the PCI Marketing Council and is a former member of the PCI Bridge Producers Committee and the QA 2020 Committee.

Kyle R. Knop

AIA, CSI, CDT, VICE PRESIDENT/ SENIOR PROJECT MANAGER, ZIMMERMAN ARCHITECTURAL STUDIOS INC., MILWAUKEE, WISC.

Bringing 25 years of technical and construction experience, Kyle R. Knop is an award-winning, licensed architect and project manager focusing on government and public institution projects. He has worked on a broad range of municipal, health care, corporate, commercial, industrial, and retail projects with precast concrete being a fundamental material for many of those developments. A collaborative leader, Knop has demonstrated a successful history building consensus with project stakeholders, engineering teams, and product manufacturers to find the best solutions that meet his clients' needs and budgets. Knop is a member of the American Institute of Architects and holds a bachelor's degree from the University of Wisconsin–Milwaukee.

All-Precast Concrete Solution Award and Bridge with a Main Span up to 75 Feet Honorable Mention

PROJECT TEAM:

Owner and Engineer of Record: New Mexico Department of Transportation, Santa Fe, N.M.

PCI-Certified Precast Concrete Producer: Castillo Prestress, Belen, N.M.

General Contractor: AUI Inc, Albuquerque, N.M.

Project Cost: $2.2 million

Project Size: 1,470 ft^2

NM 50 OVER GLORIETA CREEK

GLORIETA, NEW MEXICO

New Mexico Route 50 (NM 50) serves Glorieta, N.M., to the west and Pecos, N.M., to the east. The nearly 100-year-old crossing over Glorieta Creek exhibited severe deterioration and needed to be replaced. However, the closure of the bridge would force residents living east of the bridge to detour 18 miles to get to Santa Fe, N.M. In addition, the National Park Service had concerns that construction would disturb local flora and fauna and wanted to maintain the bridge's historic setting. An all-precast concrete structure helped the New Mexico Department of Transportation (NMDOT) to limit the closure time for residents and minimize the site impact.

"Given its ability to be quickly prefabricated off site and stored until needed, precast concrete was the best solution," recalls Richard C. Castillo, president and CEO of Castillo Prestress. "Speed was of the essence to minimize the economic impact on the community as well as the inconvenience."

The bridge is within the Pecos National Historical Park where the Battle of Glorieta Pass occurred during the U.S. Civil War. An adjacent historic well, witness trees, building, and stone wall from the Civil War era had to be protected during construction. Using a low-profile cross section reduced the visual impact of the bridge, and the aesthetic enhancements made in the design helped build community support for the project.

Construction was reduced to a narrow right-of-way, and the road closure was limited to seven weeks. "Precast concrete was selected to speed construction, minimize on-site formwork, and minimize the disruption to the historic and environmentally sensitive site," says Kimberly Coleman, PE, project engineer for NMDOT. "In addition, we needed a durable structure to withstand deicing chemicals and snowplows

> *"This project is in a visually stunning location with huge historical significance. To the traveling public, the newly constructed bridge seems to disappear into the landscape."*
> **—Kimberly Coleman, New Mexico Department of Transportation**

through the winters." Given its historic setting and environmental sensitivity, the bridge's surroundings had to be protected during construction. "The witness trees that date back to the Civil War on each side of the road were preserved," Coleman says.

TIGHT SITE

To limit the impact of construction, a 60-ft right-of-way was allocated for construction. Given the restricted access, crane swings, piece weight, and crane lifting capacity were all evaluated during design to ensure everything could be placed from one location. All demolition equipment for removal of the old bridge operated on the west side of the creek, opposite from the historic structures. The 1923 bridge was cut apart and lifted out from above to protect the environmentally sensitive stream below and the wetlands downstream. Existing abutments were left in place to preserve the flow characteristics of the creek, to preserve the existing aesthetics of the site, and to protect the new substructure.

The project used accelerated bridge construction (ABC) methods such as all-precast concrete bridge elements, which included abutment caps, wing walls, slab beams, and approach slabs. With no staging area, all-precast concrete components were delivered on a just-in-time schedule. This was critical because haulers had to drive in reverse for the last mile approaching the site since there was no room to turn around.

"This project honed our skills for future ABC projects" says Castillo. "The bridge was completed on time due to the combined efforts of the project team, and collectively we developed design and constructability details that will enhance our ability to offer fast-track construction projects to the community." To achieve the project's durability goals, tight quality control in the precast concrete manufacturing plant was critical, and a high-strength, low-permeability concrete mixture design was specified.

Additional durability measures used to extend the life of the structure included the use of stainless steel reinforcement, which resists corrosion, and the use of ultra-high-performance concrete (UHPC) in the joints to further resist the deterioration of the deck. The all–precast concrete bridge required precise fabrication to ensure proper reinforcement and embed placement, piece dimensions, and installation tolerances. As a result of this project, NMDOT has revisited some quality assurance and quality control procedures to facilitate smoother assembly in the future. Similarly, Castillo Prestress is exploring the use of slender UHPC structural elements, which can bring further advantages to a project such as minimizing construction-site footprints, greater durability, longer spans, smaller bridge profiles, lower owner costs, and less economic impact on nearby communities.

Photos: James Hirsch, Environmental Analyst, New Mexico Department of Transportation and NMDOT Bridge Bureau and AUI, Inc.

The unique engineering and construction challenges did not deter the project team. The result is a durable bridge with a projected long service life that was built quickly. Precast concrete was key to preserving the historic and environmentally sensitive project site. Because the abutment and superstructure elements were fully precast concrete, no formwork was required within the creek, construction vibration and traffic were minimized, and concrete pours were limited to the UHPC connections.

Harsh winter weather means this bridge will be repeatedly subject to deicing chemicals and snowplows. The low-permeability concrete mixture design coupled with controlled curing produced a quality finish that will limit infiltration of harmful salts and increase the durability and longevity of the bridge. Precast concrete was also key to achieving the tight construction schedule with the limited road closure window. Because the labor-intensive and time-consuming formwork and long concrete cure times required for traditional construction were eliminated, the road was reopened with one day to spare.

KEY PROJECT ATTRIBUTES

- **The all–precast concrete bridge was selected to minimize disruption to the site, the traveling public, and the national historic park that surrounds the structure.**
- **The limited time for road closure and the narrow right-of-way necessitated a quick and clean solution for this simple-span structure.**
- **For extra corrosion resistance, stainless steel reinforcement was used and UHPC connects the precast concrete elements.**

PROJECT AND PRECAST CONCRETE SCOPE

- **The bridge replacement included two abutment caps, four wingwalls, seven prestressed concrete slabs, and four approach slabs.**
- **Precast concrete erection took six days, and the road was closed for seven weeks, including demolition.**
- **Construction started in June 2021 and was completed in October 2021.**

Sustainable Design Award and Rehabilitated Bridge

PROJECT TEAM:

Owner: North Carolina Department of Transportation, Raleigh, N.C.

PCI-Certified Precast Concrete Producers: Eastern Vault Company, Princeton, W.Va.; Ross Prestress, Knoxville, Tenn.,

Engineer of Record: AECOM, Raleigh, N.C.

General Contractor: PCL, Denver, Colo.

Project Cost: $16 million

Project Size: 1125 linear ft

SWIFT ISLAND HISTORIC ARCH BRIDGE REHABILITATION AND WIDENING

ALBEMARLE, NORTH CAROLINA

Outside of Charlotte, N.C., the majestic Swift Island Arch Bridge spans the Pee Dee River. Its unique history harkens back to events that occurred before it was built. Just a few years earlier, in 1922, a three-span, open-spandrel concrete arch bridge had been erected to cross the river. Then, to make way for a dam and hydroelectric plant, the crossing was flooded to create Lake Tillery.

The new, higher-elevation Swift Island Arch Bridge was constructed to replace the original bridge, and the older bridge was destroyed. The original bridge's demise provided valuable information on bridge construction and demolition. In what would become known as the "Battle of Swift Island Bridge," the U.S. Army tried various techniques to demolish it. First, the bridge was overloaded with weight, then it was bombed from the air, and, finally, explosives were used to bring it down.

The new Swift Island Bridge opened in 1927, and a more modern parallel span was built downriver in the 1970s. In 2005, the Swift Island Bridge crossing was closed temporarily, so the second span had to carry traffic in both directions. Limited to only one lane of traffic, the 1927 bridge was slated to be replaced in 2003 when the second battle of Swift Island Bridge began in an effort to save its historic properties.

To address structural deterioration and weight restrictions, the bridge had to be widened and upgraded. The grand

"[The judges] saw a great benefit from the use of precast deck panels to improve the ease and speed of construction for the new floor system."
—Todd Lang, HDR Engineering

old structure was eligible for the Historic Register, and residents were keen on preserving it. Rather than replace the bridge and convert it into a bike and pedestrian facility, the project team opted to replace and widen the superstructure, using precast concrete girders, deck slabs, and fascia panels that replicate the original design.

"The use of precast concrete helped to preserve the original arches rather than having to demolish the bridge and build a new conventional structure. This preserved an historic resource while providing significant cost savings for the North Carolina Department of Transportation (NCDOT)," says John Sloan, PE, North Carolina bridge program manager for AECOM. "To preserve the existing arches and piers without overstressing them, precast concrete added redundancy to the structural system and reduced bending moments in the original members in order to carry vehicular loads in a safe manner," he adds.

The design featured precast and prestressed concrete box girders and deck panels, as well as mild reinforced precast concrete fascia panels. The spread box girders simplified construction, and a simple closure pour allowed the box girders to be continuous from pier to pier over the spandrel bents. This design established full flexural continuity of the girders before the precast concrete deck panels were placed on the bridge, which relieved loading and flexural demands from the arch ribs. The precast and prestressed concrete deck panels facilitated construction by serving as a stay-in-place form for the cast-in-place deck. Placing the precast concrete deck panels on the bridge ahead of the deck placement also helped relieve and balance the load on the arch ribs.

DECONSTRUCTION

"The bridge was first deconstructed down to its arches and rebuilt with a wider bridge deck, so its architectural character and detail remained intact," says Kevin Fischer, NCDOT assistant state structures engineer, field operations. This process involved creating a four-dimensional model to accurately predict structure demands throughout construction and developing a construction sequence that would be beneficial for the original arches and piers. Those components had limited capacity, so a detailed construction sequence and structure articulation were provided to prevent overstress.

Further complicating schedule demands were the location of the structure and access limitations. "The remote location of Lake Tillery and the complex construction sequencing needed to avoid overstressing the arches warranted the use of precast concrete. Precast concrete beams reduced the construction timeline and improved constructability. The unique continuity details of the precast concrete beams allowed the elimination of several joints in the bridge to reduce future maintenance needs," says Fischer.

Photos: AECOM.

The project required a delicate balance to meet all the project goals, which were to complete the project as quickly as possible to minimize the inconvenience to those traveling by boat or car; keep the bridge in balance to avoid damage to the arches or foundation; tread lightly across the beautiful Piedmont area and Lake Tillery; and preserve the historic character of the existing bridge.

The team made every effort to preserve the architectural character by using precast concrete fascia panels. These panels were specified to facilitate construction, provide a durable solution, and be aesthetically pleasing. "The historic preservation team was pleased that the bridge could be preserved, and they were very satisfied that the aesthetics captured the architectural character of the original bridge," notes Sloan.

The original concrete arch foundation lives on through the efforts of the project team. "Not only did we save the department of transportation considerable cost and accelerate the completion of construction, but we also preserved the history of this structure," Fischer says. "It's gratifying to see the results, which provide a safer passage for local residents as well as an historic appearance."

KEY PROJECT ATTRIBUTES

- **Preserve the 95-year-old concrete piers and arches.**
- **Use precast concrete girders, deck panels, and fascia panels to replicate the original aesthetics.**
- **This design-build project was designed with a four-dimensional finite element model to accurately predict geometry and load demands for all precast concrete elements.**

PROJECT AND PRECAST CONCRETE SCOPE

- **The four arch spans are 210 ft each, and each arch span has 12 spans between spandrel bents.**
- **The project used 212 girders, 849 deck panels, and 132 fascia panels.**
- **The project was completed in May 2021.**

2023 PCI DESIGN AWARDS

Transportation AWARDS

Transportation Awards JURY

Reggie Holt

SENIOR STRUCTURAL ENGINEER, FEDERAL HIGHWAY ADMINISTRATION, WASHINGTON, D.C.

Reggie Holt is a Senior Bridge Engineer and the concrete bridge specialist for the Federal Highway Administration (FHWA) office of Bridges and Structures at FHWA headquarters in Washington D.C. He is responsible for national policy and guidance on bridge design and analysis. Prior to his current position with FHWA, Holt worked for bridge design consultant T.Y. Lin International. He designed and managed multiple complex concrete bridge structures during his 15-year career at T.Y. Lin.

Holt holds a bachelor of science and Masters of Science degree in Civil Engineering from the University of Maryland. He is a registered professional engineer and member of multiple technical committees, including: ex-officio for the AASHTO T-10 Committee on Concrete Design, Transportation Research Board Concrete Bridges Committee, PTI Post-Tensioned Bridge Committee, PTI Grouting Committee, PTI Cable Stay Bridge Committee and the PTI/ASBI Grouted Post-tensioning Committee. Holt has participated on multiple research technical review panels and has served on multiple Blue Ribbon Panels and Expert Task Groups throughout his career.

Bijan Khaleghi

STATE BRIDGE DESIGN ENGINEER, WASHINGTON STATE DEPARTMENT OF TRANSPORTATION BRIDGE AND STRUCTURES OFFICE, OLYMPIA, WASH.

Bijan Khaleghi was State Bridge Design Engineer with Washington State Department of Transportation, and adjunct faculty at Saint Martin's University. He received his Master and Doctor of Engineering degrees from the National Institute of Applied Sciences, France. Khaleghi is a member of AASHTO Technical Committees T-8 Movable Bridges, T-10 Concrete, and T-20 Roadway Tunnels. He is a member of PCI and ASBI Bridge Committees, Chair of PCI Seismic Subcommittee, TRB Committees AFF30 Concrete, Aff50 Seismic, and International Road Association, PIARC. He has received IBC, PCI, ASCE, SEI, and TY Lin awards.

Todd Lang

PE, SE, SENIOR BRIDGE ENGINEER, HDR ENGINEERING, OMAHA, NEB.

Todd Lang is a project manager, senior bridge engineer and Professional Associate at HDR Engineering. He has a Bachelor's Degree in Civil Engineering from North Dakota State University and a Master's Degree in Civil Engineering (Structures) from Purdue University. He has 29 years of experience in the design, analysis and inspection of bridges and other transportation-related structures. His bridge experience includes designing concrete, steel, and timber bridges to carry vehicles and pedestrians over highways, railroads, streams, and major rivers. The concrete bridges include cast-in-place, prestressed, and post-tensioned structures. The steel structures include rolled beams, curved plate girders and, deck trusses.

Lang also has experience designing bridge rehabilitations, retaining walls, drainage structures, and wind turbine foundations. He has completed many bridge-related preliminary studies, including rehabilitation-versus-replacement studies, structure type studies and span arrangement studies.

Bridge with a Main Span Up to 75 Feet

PROJECT TEAM:

Owner: Massachusetts Department of Transportation, Boston, Mass.

PCI-Certified Precast Concrete Producer: JP Carrara & Sons Inc., Middlebury, Vt.

Engineer of Record: Gill Engineering Associates, Needham, Mass.

General Contractor: J.F. White Contracting Co., Framingham, Mass.

Project Cost: $55 million

Project Size: Eight bridges with span lengths from 35 ft 6 in. to 70 ft 9 in.

ACCELER-8 I-90 BRIDGE REPLACEMENT PROJECT

SOUTHBOROUGH AND WESTBOROUGH, MASSACHUSETTS

The Acceler-8 Interstate 90 (I-90) bridge replacement project outside of Boston epitomized rapid bridge-replacement and bridge-bundling techniques. The challenge was to replace eight bridges in eight weekends during the summer of 2021. The use of precast concrete components was essential to the successful completion of every crossing.

Initially, the Massachusetts Department of Transportation (MassDOT) considered prefabricated bridge units (PBUs) composed of steel beams with a precast concrete deck. However, the final design used Northeast Extreme Tee Deck (NEXT D) beams as an alternative technical concept along with precast concrete approach slabs and abutment caps.

"We chose an innovative solution and selected precast, prestressed NEXT D beams. NEXT D beams were more economical than the proposed PBU option from the base technical concept, due to lower material and fabrication costs, including reduced handling. PBUs require fabrication in both steel and precast concrete plants, whereas NEXT D beams require fabrication in only a precasting plant," says Joseph Gill, PE, president, Gill Engineering.

"Precast concrete helped to overcome challenges such as as the development of the design details to accommodate Accelerated bridge construction during the weekend closure. These details need to be simple, uniform as much as possible throughout the project and compatible with the contractors and schedule, and would provide a minimum of 75 year service life."

–Bijan Khaleghi, Washington State Department of Transportation

Photos: *Gill Engineering Associates, Inc and Tetra Tech, Inc.*

The use of a single-stem NEXT D beam was a distinctive feature of this project and allowed for a more efficient cross-section design. However, stability of the beam during storage, transportation, and erection needed to be addressed. NEXT D beams are extremely robust. Their beefy stems can tolerate significant deterioration before structural integrity is compromised. The fabricator also used a high-performance, self-consolidating concrete (SCC) mixture, which typically achieves 28-day compressive strength of 10,000 psi. The NEXT D beams were designed for a compressive strength of 8000 psi, and the additional strength will improve the structure's service life. This same SCC mixture was used in the abutment caps, approach slab panels, and moment slabs, all of which were designed assuming a 4000-psi strength. The NEXT D beams will also reduce maintenance costs by eliminating the need to repaint steel beams in the future.

LONG SUMMER WEEKENDS

To prepare for the targeted weekend road closures, cast-in-place concrete micropile foundations, abutment stems, and wing walls were constructed and backfilled under the existing approach spans in the months before the planned closures. The six superstructure replacements and the two bridge replacements were completed over six weekends of traffic diversion. During each weekend closure, all traffic was consolidated into one barrel of the roadway (eastbound or westbound), carrying two lanes in each direction. This traffic setup was implemented with crossovers and movable barriers. Typically, demolition would be completed by around 10:00 a.m. on Saturday, and after cleanup, precast concrete erection would begin around 12:00 noon and would be completed by approximately 6:00 p.m. Each completed bridge was reopened to traffic by 5:00 a.m. on Monday.

Each weekend project required 60 precast concrete pieces for the accelerated bridge construction. Some of the precast concrete pieces weighed more than 60,000 lb, so a heavy crane was required to hoist them into place. Trucks delivering precast concrete bridge components from the precast concrete producer's facility were dropped at a storage lot and during the weekend were staged along I-90 and local roads.

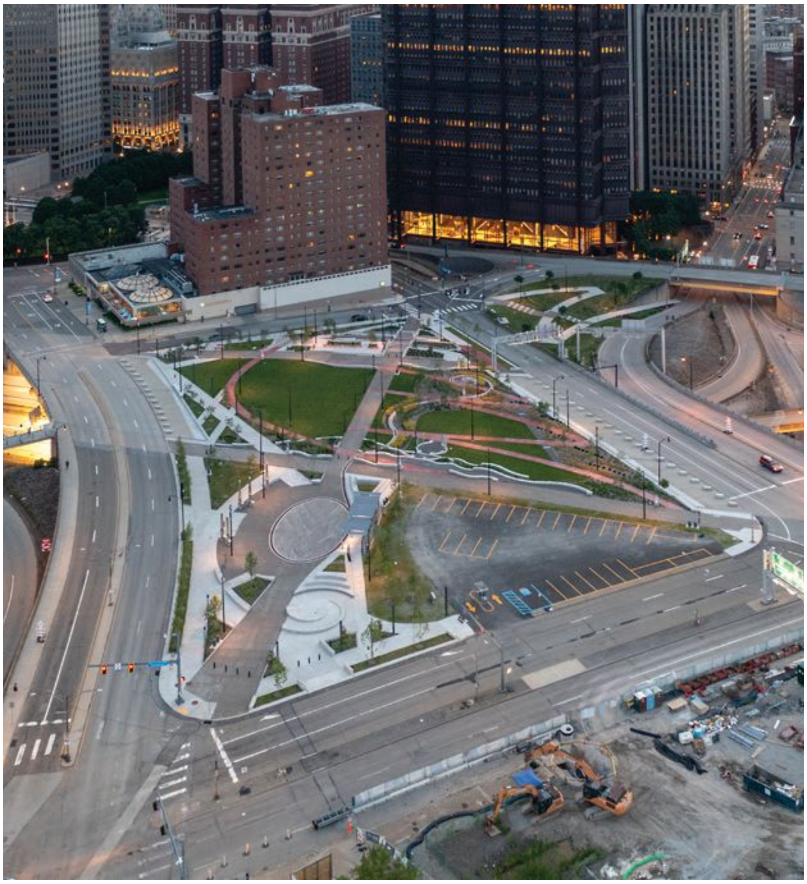
"One challenge was addressing the beam camber," says Gill. Because the design used an 8-in.-thick deck and no haunch, "all variations in the camber needed to be addressed with variable thickness of paving on the approaches and along the beams." The prestressed beams were surveyed after fabrication to determine the actual camber. The project team revised the seat elevations during construction by lowering the horizontal saw cuts in the rehabilitated abutments and lowering the seat elevations of the cast-in-place abutments, to ensure that the final beam position would properly conform to the roadway profiles. After final placement, additional surveying ensured that the non-structural asphalt overlay pavement would meet the final roadway profile and provide a smooth ride.

KEY PROJECT ATTRIBUTES

- **MassDOT bundled replacement projects for eight bridge structures over I-90 during the summer of 2021.**
- **Innovative construction techniques and precast concrete systems were used to upgrade the crossings between Worcester and Boston (which serve more than 100,000 drivers per day) while minimizing the project's impact on the traveling public and local residents.**
- **The use of a single-stem NEXT D beam was a distinctive aspect of the project and allowed for a more efficient cross-section design.**

PROJECT AND PRECAST CONCRETE SCOPE

- **Replace eight bridges in eight weekends over the Massachusetts Turnpike (I-90).**
- **The six superstructure replacements and the two bridge replacements were completed over six weekends of traffic diversion. Bridge demolition and reconstruction took place over 55-hour weekend closures.**
- **Each bridge had five NEXT D beams and one single-stem NEXT D beam as well as precast concrete abutment caps, approach slabs, and moment slabs. In total, 48 NEXT D beams were used.**



Non-Highway Bridge Co-winner

PROJECT TEAM:

Owner: City of Pittsburgh, Pa.

PCI-Certified Precast Concrete Producer: Northeast Prestressed Products, Cressona, Pa.

Engineer of Record: HDR, Pittsburgh, Pa.

General Contractor: Fay, S&B USA Construction, Pittsburgh, Pa.

Project Cost: $30 million

Project Size: 52,000 ft²

I-579 URBAN OPEN SPACE CAP

PITTSBURGH, PENNSYLVANIA

The construction of Interstate 579 (I-579) through Pittsburgh, Pa., more than 60 years ago separated the Hill District from the downtown. With the help of federal grant money from the Transportation Investment Generating Economic Recovery program, the Urban Open Space Cap project creates a new modern park with room for outdoor events and reconnects the disenfranchised district to the city's economic core.

The I-579 project functions as a "cap" over the interstate that provides a walkable link from the Hill District to the downtown. The new park includes art installations, story walls, outdoor classroom space, and an amphitheater, as well as bike and pedestrian pathways.

After evaluating several options, the design team selected adjacent precast concrete box beams for several reasons: The beams are strong enough to support the unique park loading, including up to 5 ft of soil. Locally available bridge elements were economical. And precast concrete box beams were ideal for the urban site because they could be delivered with minimal site disturbance and lifted from adjacent parcels to minimize the impact of the construction on the highway below.

"This project utilized a precast prestressed box beam solution to provide the needed strength, resilience, and aesthetics for a three acre urban park that was constructed over top an active interstate."
– Reggie Holt, Federal Highway Administration

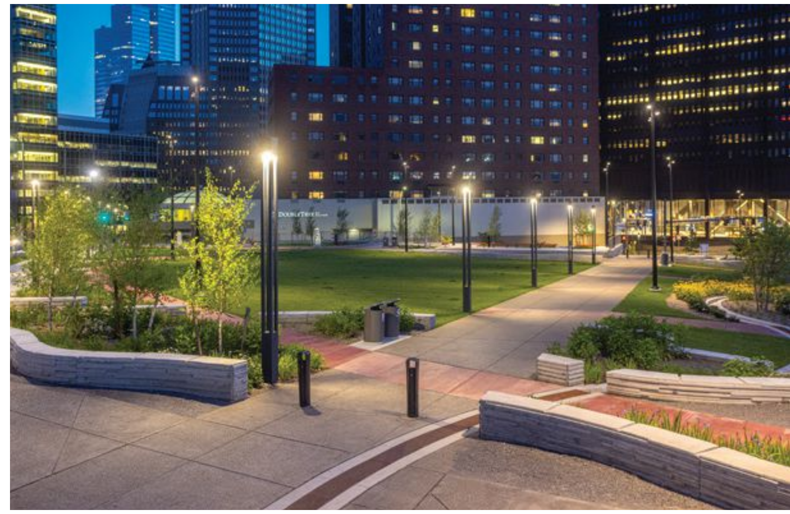
Because the structure is located over the interstate, minimizing future bridge maintenance was a high priority. The precast concrete beams do not need to be painted and will be durable. The beams also provide a smooth soffit for aesthetics under the bridge, and they offer a consistent surface for attachment of the under-bridge lighting system.

The highway spanned by the new structure varies in width due to the presence of four ramps merging and diverging from the main roadway. Several of these ramps include retaining walls on spread footings, and it was important to ensure that the project would not have an adverse impact on these components. Very little gore area was available between the roadways to accommodate piers for the new structure. The new structure and park also had to tie into the existing sidewalks, which involved 20 ft of elevation change.

The design team for the bridge structure and park addressed these challenges, and others, through innovative structural and landscape design solutions. New abutments were constructed behind the existing retaining walls, which were trimmed to accommodate the new beams. These abutments were supported by over 200 drilled micropiles, which were used to minimize disturbance to the existing walls. Adjacent prestressed concrete box beams were used for the superstructure, which was divided into three units to allow transverse post-tensioning of the beams, and better match the span configurations of the adjacent structures. An 8-in.-thick cast-in-place concrete deck slab was placed on the beams to act compositely and achieve full load-sharing among the beams. The deck contained two layers of reinforcement steel in each direction to provide a robust system. The cast-in-place concrete deck included redundant waterproofing features to protect the entire superstructure. New piers were founded on drilled shafts that could be installed in narrow gore areas and transition directly into slender multicolumn bents, to limit impact to the roadway template. Compatibility with requirements of the Americans with Disability Act was established for the significant grade change across the park through walkway switchbacks into the tiered raingardens at the northwest corner.

BRIDGING THE GAP

"Of all the challenges this project faced, developing a viable structural solution for the bridge was the greatest hurdle. The new bridge had to 'fill the gap' between the two existing vehicular bridges, while maintaining the required vertical clearance above the interstate and carrying sufficient soil depth to sustain plantings on the surface," says Nicholas



Photos: *Courtesy of HDR © 2022.*

Burdette, PE, Northeast Region bridge lead, HDR. The project team developed the preferred precast concrete adjacent box-beam solution to minimize initial costs, limit the bridge's impact on existing structures and interstate traffic, and use low-maintenance components.

The complexity of the constrained urban site was exacerbated because there are no standard design codes for bridges carrying a park. The project team developed specific criteria to meet the demands associated with the intended use of the park area. They evaluated both the final in-service condition of the bridge and the construction loadings associated with placing the fill and amenities on the bridge.

Working within the congested urban core was a major challenge and required careful planning. This project included 14 phases of traffic for demolition, substructure construction, and superstructure construction work, including installation of more than 1 million lb of reinforcing bars; 126 box beams, each weighing 140,000 lb; 1800 ft of curved architectural walls on top of the deck structure; 50,000 ft^2 of reinforced architectural sidewalks; and 14,000 ft of micropiles to support the abutments.

KEY PROJECT ATTRIBUTES

- **As Pennsylvania's first park over an interstate, this urban, 3-acre green space reconnects Pittsburgh's historic Hill District with the city's downtown.**
- **The precast concrete adjacent box-beam superstructure is both economical and strong enough to support the unique park loading, including up to 5 ft of soil.**
- **The precast concrete beams also support the hanging lighting for the vehicular tunnel below.**

PROJECT AND PRECAST CONCRETE SCOPE

- **The project used 12,190 linear ft of 48 × 66 in. precast, prestressed concrete box beams.**
- **The maximum span length is 121 ft.**
- **Erection of the 126 precast concrete adjacent box beams took 38 days, and the entire project was completed in November 2021.**

Non-Highway Bridge Co-winner

PROJECT TEAM:

Owner: San Diego Association of Governments, San Diego, Calif.

PCI-Certified Precast Concrete Producer: Oldcastle Infrastructure, Perris, Calif.

Precast Concrete Specialty Engineer: Oldcastle Infrastructure, Fontana, Calif.

Engineer of Record: WSP USA, San Diego, Calif.

Design Oversight Engineer: TY Lin, San Diego, Calif.

General Contractor: Mid-Coast Transit Constructors, joint venture of Stacy and Witbeck and Herzog and Skanska

Construction Management/Contract Administration/Quality Assurance/Field Engineering: Kleinfelder Construction Services, San Diego, Calif.

Project Cost: $2.17 billion

Project Size: 5570 ft in length, 197,604 ft^2

MID-COAST EXTENSION OF THE UC SAN DIEGO BLUE LINE TROLLEY

SAN DIEGO, CALIFORNIA

As one of San Diego's most important transportation projects, the Mid-Coast Extension of the University of California San Diego (UCSD) Blue Line extends the San Diego Metropolitan Transit System with 11 miles of double tracks. This light-rail addition goes from downtown San Diego to the campus of UCSD. It provides an alternative to congested freeways and connects the corridor with areas served by the existing trolley system.

At a cost of more than $2 billion, the extension is one of the largest infrastructure projects in the San Diego area. In addition to the new tracks, this project encompassed eight bright crossings, several miles of aerial viaduct structures, five at-grade stations, and four aerial stations. At five of these stations, an additional 1170 parking spaces were added.

GENESEE VIADUCT

For the viaduct constructed within the median of Genesee Avenue, the original design called for another building material, but the project team opted to splice precast concrete girders on site. The resulting viaduct is the first curved, spliced precast concrete U-girder light-rail transit bridge in Southern California. By constructing this viaduct, the project

"Efficiency with which the segments could be erected and spliced together, minimized traffic interruptions and impacts to adjacent land uses, and shortened the overall construction duration of the project while producing a durable, long-lasting final project."
– Todd Lang, HDR Engineering

Photos: MCTC.

team has provided new techniques for future infrastructure projects that can be useful in minimizing traffic disruptions. The Genesee Viaduct is the result of a collaborative process in which team members used innovative design techniques, limited construction costs, and an optimized schedule. It was critical to maintain local traffic and minimize the impact on the surrounding community, and these priorities were the primary drivers as stakeholders selected the structure type and construction methods. Only nighttime closures of major intersections on Genesee Avenue were considered.

Precast concrete U-girder construction was selected for most of the viaduct to minimize falsework. "The falsework design would have to be continuous, which means the major intersections at which the viaduct crossed would be completely cut off for the duration of the construction through each intersection," says Vladimir Kanevskiy, PE, engineering manager, WSP USA.

Precast concrete girders were fabricated off site and transported to the construction site. There, the precast concrete girders were spliced together with a cast-in-place (CIP) closure pour for continuity under the final loading condition. This girder layout reduced hauling costs, limited the girder weight to under 100 tons, and removed the need for specialized hauling equipment.

Three frame types of assorted construction techniques, girder assembly, and splicing operations were used on the viaduct design. Nine precast concrete girder frames consisted of precast concrete U-girders (Caltrans "bathtub" girders) spliced by one- or two-stage post-tensioning. Girders for spans over intersections were spliced in a staging area away from traffic. On both sides of the intersection sat temporary shoring towers, where the spliced segment was lifted and placed. To splice the girder segments on the shoring towers that did not cross traffic, a second post-tensioning tendon was used. A second stage of post-tensioning was performed after all individual girders were spliced, which connected all the segments. This technique created continuity between the expansion joints. The four frames that were left were spliced and tensioned in one stage.

Crossing over La Jolla Village Drive sits the longer span part of the viaduct, which was 225-ft-long. Due to its length, it could not be lifted and placed in one piece onto temporary shoring towers. The project team used a hybrid precast concrete/CIP superstructure, which reduced the spliced length while still using the girder construction in adjacent spans. The CIP girder segments were connected to precast concrete girder segments by post-tensioning and closure pours.

Two aerial side-platform stations – each station within a single structural frame – are served as the Genesee Viaduct. Transverse beams connected to superstructure girders support the side platforms. Single-stage post-tensioning was performed at all station frames.

Three superstructure types addressed the different types of loading and frame construction. Two 96-in.-deep U-girders connected with a 9-in.-thick CIP deck were used as the cross section at the precast concrete girder frames. Superstructure depth is constant in all precast concrete girder frames.

The Mid-Coast Extension is recognized as the most important transportation improvement project in San Diego for expanding capacity and accommodating future travel demands in the region. The extension provides a direct link from the United States/Mexico border to University City and is a great addition to the region's public transit system.

KEY PROJECT ATTRIBUTES

- **The light rail runs along the center of Genesee Avenue, which is critical for providing vehicle access to the University of California San Diego campus, residences, hospitals, retail, schools, and employment. One project requirement was that major intersections must be kept open and operational throughout construction.**
- **Full closure of intersections where precast concrete girders crossed over live traffic was permitted only for short periods, one intersection at a time.**
- **Precast concrete girders were spliced at a staging area near the construction site and then transported to the site. The spliced segments were placed on shoring towers during the nighttime closure.**

PROJECT AND PRECAST CONCRETE SCOPE

- **After girders were spliced together, the 35 spans ranged in length from 138 to 192 ft.**
- **The precast concrete Caltrans U-girders have a 10-in.-thick webs and a 9-in.-thick bottom flange.**

Transportation Special Solution

PROJECT TEAM:

Owner: Baltimore Gas and Electric, Windsor Mill, Md.

PCI-Certified Precast Concrete Producer: Coastal Precast Systems, Chesapeake, Va.

Engineer of Record: Sargent & Lundy, Elkridge, Md.

Structural Engineer: Moffatt & Nichol, Baltimore, Md.

General Contractor: McLean Contracting Company, Glen Burnie, Md.

Project Manager: Burns & McDonnell, Windsor Mill, Md.

Project Cost: $5.1 million

Project Size: 67 precast concrete pile caps and 62 precast concrete panels

KEY CROSSING RELIABILITY INITIATIVE

BALTIMORE, MARYLAND

One of Maryland's largest electric utility providers, Baltimore Gas and Electric (BGE) owns and operates a high-voltage transmission grid. Most of BGE's 230-kV lines circling Baltimore are aboveground; however, at the Key Bridge, the utility has underwater lines, which were put into the riverbed in the 1970s. The 2.5-mile-long portion of the line that crosses the Patapsco River through the main shipping channel is located approximately 10 to 15 ft below the riverbed. Having been in service for over 50 years, this portion displayed signs of deterioration. Given that this section was critical for the resiliency of the grid system, BGE planned to replace it with a new transmission line crossing.

Various alternatives were analyzed, with due consideration given to cost, design complexity, environmental impact, stakeholder preferences, permitting complications, and interruption of shipping. In 2015, the project team selected overhead lines incorporating tall towers in the river as the preferred solution, and final design was completed by the end of 2019.

The crossing includes eight towers, with heights that vary between 160 and 400 ft. The tallest towers are in the water adjacent to the shipping channel to provide a minimum of 230 ft of clearance for ship traffic. The towers in the water required independent vessel collision protection structures to prevent ships from striking the towers or their foundations. A detailed, probabilistic vessel-collision risk analysis

"The increased durability achieved with using precast components constructed in a plant environment were able to meet the project's 75 year service life requirement in this harsh marine environment."
– Reggie Holt, Federal Highway Administration

was performed per requirements set forth in the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*. The protection structures have a continuous concrete ring around each foundation, the largest being 14 ft wide, 7 ft deep, and 633 ft long in perimeter. Both the foundation and protection structures are composed of layers of precast and cast-in-place (CIP) concrete, supported by steel pipe piles.

Precast concrete was incorporated into the earliest design concepts and was a dominant technology in all over-water construction, reducing the construction time of the in-water structures, improving the design life of reinforcement, reducing the amount of CIP concrete formwork, and improving the accuracy of perimeter fender bolt placement.

For the work over water, the use of CIP concrete would have been complicated and time-consuming. All concrete elements directly above open water were designed and detailed as precast concrete. Only narrow CIP closure pours between precast concrete planks were required over water. Most precast concrete elements were rectangular, but trapezoidal and bent-angle shapes were also used for unique structural boundaries. "Considering that all precast concrete pile caps and panels over water were 2-ft thick, the avoidance of horizontal formwork avoided significant effort," says Mehedi Rashid, structural engineer, Moffatt & Nichol. "With so much work to be performed in an accelerated construction schedule, precast concrete was the most effective method to achieve a successful on-time completion of the project."

CHANNEL CROSSING

Of the eight towers required to cross the Patapsco River, tower 1 is located at BGE's Hawkins Point substation, towers 2 through 6 are in the water, and towers 7 and 8 are located at Sollers Point. The largest span (2200 ft in length) crosses the Fort McHenry channel, which is the primary shipping channel entering the Baltimore Harbor.

The precast concrete configuration consists of precast concrete caps installed on top of the piles, with precast concrete planks spanning between the caps to form a continuous precast concrete working surface over the water. A total of 67 pile caps and 62 panels were used for the project. The precast concrete pile caps range in weight from 8 to 47 tons.

The contractor's substitution of a single, monolithic precast concrete foundation piece at three of the towers pro-

Photos: *Ben Frank, McLean Contracting, and Mazi Chiles, McLean Contracting.*

duced a massive square precast concrete pile cap weighing 164 tons. The project used marine concrete to provide a 75-year design service life and conducted strict quality control measures along with field and production testing to achieve the design objectives.

Stakeholders for this significant infrastructure project were cognizant of environmental sensitivity issues, budget concerns, and the project's economic impact on the community. Compared with the underwater option, which would have required jet-plowing submarine cable through the river bottom, the overhead option was more environmentally sound. Also, building underground cables would have cost approximately twice as much as the overhead project. Furthermore, installing overhead lines had less impact on operations in the Port of Baltimore than the underground option would have had.

KEY PROJECT ATTRIBUTES

- **New transmission towers and 2 miles of high-voltage power lines cross the Patapsco River next to the Francis Scott Key Bridge, improving the reliability of utility delivery for customers.**
- **The contractor's innovative use of pile-driving templates enabled the installation of large-diameter piles within tolerance, and accelerated construction.**
- **The use of precast concrete for all work over water reduced safety risks and shortened the project schedule.**

PROJECT AND PRECAST CONCRETE SCOPE

- **The 2-ft-thick precast concrete piles range in size from 8 ft × 8 ft 6 in. single-pile caps to 19 ft × 16 ft 6 in. double-pile caps.**
- **Precast concrete panels spanning between pile caps are 2-ft-thick trapezoidal shapes and range in size from 12 ft × 8 ft to 29 ft 6 in. × 14 ft.**

PCI
Precast/Prestressed
Concrete Institute