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THE CONCRETE BRIDGE MAGAZINE

SPRING 2024

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SIMPSON GUMPERTZ & HEGER THRIVES ON CHALLENGING PROJECTS

Using engineering expertise and applied science, SGH provides integrated engineering solutions

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EDITORIAL

Photo: PCI.

No Partial Credit

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

The editorial in the previous issue of *ASPIRE*®, "Bring 'Em Along," by Dr. Krista Brown, is a great primer for all of us.

I owe a great deal of my professional engineering journey to several individuals who took the time to share knowledge and assist me along the way. My journey began more than 40 years ago at The Citadel in Charleston, S.C. The civil engineering department was known for its high academic standards, and the course load was just brutal. The professors were a notable cast of characters. They all had nicknames, several going back generations. Some of those nicknames were flattering; some are not printable.

One especially exacting professor, Thomas Dion, stood out to me for the way he combined the charm and wit of a Southern gentleman with the brutality of a sledgehammer. He was unbelievably demanding, and he did not grade on a curve. The test score you received—or "earned," as he was fond of saying—was the score recorded. I remember one of my classmates asking Professor Dion if he gave partial credit. The response is etched in my memory: "Do you get partial credit for the building you designed that partially fell with the First Lady in it? No, and you'll get no partial credit here." Much has changed in our profession in the years since I heard that statement, but those words still ring in my ears.

After college, I joined the Florida Department of Transportation (FDOT) to complete a yearlong professional engineer (PE) training program. That exceptional program, built on a rotational model, was designed to expose college grads to aspects of planning, building, and operating an infrastructure asset. We spent time in the planning, finance, bridge and roadway design, construction, traffic operations, and maintenance divisions of the department, learning how projects moved from concept to concrete.

During my years as a consultant, I constantly wrestled with the concept of training new or inexperienced engineers. We didn't have 12 months to spend developing new talent, but my exposure to the FDOT PE training model allowed me to scale a training/onboarding program that fit our office and expertise. Our firm generally preferred to assign a mentor in a single area of focus, knowing that this investment would reap benefits during the specialist's tenure in that area of civil engineering.

The challenges we face today don't just come from the rigors of the profession. Everyday circumstances, emerging technologies, local and federal policies, and declining numbers of people joining or staying in the profession all bring about new challenges.

At the recent PCI Convention, an esteemed colleague voiced concern about what he perceives to be fewer senior-level engineers in the workforce. Some of them have moved on to well-deserved retirement, but others have been lost to outside pressures and, somewhat shocking to me, to professional burnout. (My oldest daughter, who graduated from college in May 2023, shares that her peers call it "trauma bonding" and quickly assess personal impacts. Some even go as far as making several career pivots early in their work life.) This colleague was struggling to find a solution that best fit his organization. We talked about strategies to increase staffing levels, the training timeline for newly minted engineers to become "profitable," and how to approach the increasing demand for "work-life balance."

The current reality is that we are losing qualified and senior professional engineers to out-of-balance work and life conditions, and this problem needs to be addressed ASAP. When an out-of-balance condition is discovered at the jobsite, leadership gets involved to identify the needs and help the team remedy the situation. We need to take the same type of approach here. For myriad reasons, we cannot afford to lose highly experienced professionals to this out-of-balance condition.

There's no partial credit here—we are talking about people. Creative solutions must account for both sides of the equal sign. Finding and/or planning some "float time" in project delivery timelines might provide a bit of much-needed breathing room and help restore balance in the workforce. Please reassess your workload and workplace culture and your own wellness.

To help us all on our occupational journeys, PCI has launched some tools for workforce development. Please see www.pci.org/workforce for more on recruitment, retention, and wellness.

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- Retention and recruitment tools
- Legal resources for helping specialized populations
- Wellness resources for companies to support their employees
- PCI involvement strategies for long-term workforce success
- Videos to help develop and retain workers

Working toward the common goal of bolstering our workforces and guaranteeing the success of our industry for years to come, the Recruitment, Retention, and Wellness task groups are bringing resources and support to producers, PCI members, and the industry to engage everyone at a national level. Any individual can access this page featuring up-to-date resources, video materials, and information to explore the needs and questions of the precast concrete workforce at and in between PCI meetings.

pci.org/workforce

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CONCRETE CALENDAR 2024

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

April 14–17, 2024
PTI Convention
Westin Indianapolis
Indianapolis, Ind.

April 15–18, 2024
CRSI Spring Business and Technical Meeting
Disneyland Hotel
Anaheim, Calif.

April 24–25, 2024
NCBC Prestressed Concrete Bridge Seminar: Concepts for Extending Spans
Atlanta, Ga.

May 6–10, 2024
PTI Certification Week
Houston Marriott North
Houston, Tex.

June 3–5, 2024
International Bridge Conference
Marriott Rivercenter
San Antonio, Tex.

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

July 22–July 25, 2024
Bridge Engineering Institute Conference
Tropicana Las Vegas
Las Vegas, Nev.

September 9–13, 2024
PTI Certification Week
Embassy Suites by Hilton Miami International Airport
Miami, Fla.

September 15–18, 2024
AREMA Annual Conference and Expo
Kentucky International Convention Center
Louisville, Ky.

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

October 1–4, 2024
PTI Committee Days
Kempinski Hotel Cancun
Cancun, Mexico

October 20–23, 2024
ASBI Annual Convention and Committee Meetings
Loews Atlanta Hotel
Atlanta, Ga.

October 21–24, 2024
PTI Certification Week
Doubletree by Hilton Denver Hotel
Denver, Colo.

November 3–7, 2024
ACI Concrete Convention
Philadelphia Marriott Downtown
Philadelphia, Pa.

November 10–13, 2024
CRSI Fall Business and Technical Meeting
Drake Hotel
Chicago, Ill.

November 18–24, 2024
PTI Certification Week
Hilton Austin Airport
Austin, Tex.

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FOCUS

Simpson Gumpertz & Heger Thrives on Challenging Projects

The 68-year-old consulting firm uses engineering expertise and applied science to provide integrated engineering solutions for forensic investigation, design, and rehabilitation projects

by Monica Schultes

Nearly 6000 precast concrete deck panels were manufactured for the Governor Mario M. Cuomo Bridge connecting New Jersey and New York. Simpson Gumpertz & Heger consulted with Unistress Corporation on this project, fine-tuning concrete mixture proportions and optimizing constructability at the Unistress precast concrete facility. Photo: Unistress Corporation.

Simpson Gumpertz & Heger (SGH) is a national engineering firm with 700 employees. The firm's diverse experience and technical expertise fall into five primary service areas: structures, building enclosures, advanced analysis, performance and code consulting, and applied science and research. The company, which bears the name of the three Massachusetts Institute of Technology professors who founded it in 1956, now provides services to clients in several major markets, including commercial, entertainment, education, energy, government, healthcare and life sciences, industrial, residential, science and defense, and infrastructure and transportation.

The ethos established by SGH's founders—a commitment to technical excellence and integrity—still rings true today. According to Dominic Kelly, senior principal at SGH, "Our breadth of technical skills and in-house laboratory and research capabilities give us the resources to help our clients. We take pride that they frequently seek us out for their most challenging projects."

Organic Growth

From the firm's early days as fledgling consultants to its prominent place in the ENR Top 200 design firms, SGH's growth has primarily been organic and has involved strategic hiring to meet clients' needs, expanding geographically, and developing capabilities in areas complementary to their core services. With offices in Atlanta, Ga.; Boston and Waltham, Mass.; Chicago, Ill.; Denver, Colo.; Houston, Tex.; Los Angeles, Newport Beach, and Oakland, Calif.; New York, N.Y.; and Washington, D.C., SGH performs work across the United States as well as internationally.

In addition to designing new construction, SGH works extensively with aging structures and infrastructure, performing thorough structural and building enclosure condition assessments to identify, prioritize, and design appropriate repair options. Kelly says, "We also have a long-standing practice in historic preservation, which uses research, field observation, testing, and analysis to protect and extend the useful life of our communities' most treasured and historic structures."

The firm often collaborates with large institutional clients, providing solutions for aging structures. "To communicate our findings and recommendations, SGH developed a web-based asset-management tool that can be used throughout the built environment, where we capture field observations and evaluations in a structured manner and provide our clients with a living record for them to update. Our asset-management tool gives clients insight into a vast amount of collected data and the means to prioritize repair and maintenance," Kelly says.

Applied Science and Research Center

To complement their professional consulting services, SGH operates the Applied Science and Research Center (ASRC), which consists of approximately 13,500 ft^2 of laboratory facilities at the firm's Waltham headquarters. There, SGH develops and performs comprehensive testing and research to better understand

The Applied Science and Research Center at Simpson Gumpertz & Heger's headquarters in Waltham, Mass., is ISO-certified to perform a wide range of concrete testing. Photo: Simpson Gumpertz & Heger.

how materials, components, and systems behave. The ASRC's main focus areas include physical testing, environmental simulations, materials science, microscopy, and research partnerships with academic and scientific institutions. The ASRC team members—chemists, geologists, metallurgists, material engineers, and laboratory technicians—explore questions such as why materials fail, how structural connections perform, and how building or structural components will behave when exposed to specific conditions or loading parameters.

"It is in our nature to understand how structures and materials behave," says Matthew Sherman, senior principal at SGH. "Laboratory testing helps us validate innovative designs, provide evidence for investigations, and inform our repair techniques. By executing our own hands-on analyses, and through our constant questioning, we solve complex issues, satisfy our curiosity, and create an environment where we can learn and improve."

"It is in our nature to understand how structures and materials behave."

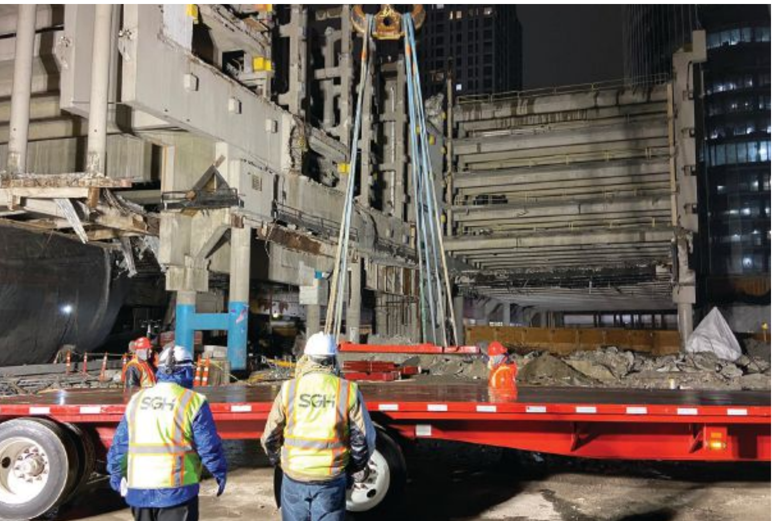
In 2022, the ASRC earned ISO certification for key concrete testing methods. The certification complements the center's American Association of State Highway and Transportation Officials (AASHTO) concrete testing lab accreditations, which include specific equipment requirements, procedures, training, and staff competency evaluations. SGH maintains active accreditations in Aggregates, Concrete, Quality Management Systems, and Concrete Materials Testing. Audits are performed by third-party inspectors to ensure that standards are maintained. The inspectors review SGH's quality-management system, how data are assessed, and how a competent, trained staff is maintained.

Concrete Anchorage

SGH values continual learning and actively works to further the standards of practice in the profession. "We have an obligation to share our knowledge outside the firm, and we participate in dozens of organizations by holding leadership positions, participating on codes and standards committees, and conducting research," says Neal Anderson, technical director at SGH.

Anderson has contributed his expertise to the industry by being active in the American Concrete Institute's (ACI's) concrete anchorage committee for many years. SGH took an active role in developing the new provisions for cast-in-place and post-installed anchors that were introduced into Article 5.13 of the *AASHTO LRFD Bridge Design Specifications*[1] in 2017. According to Anderson, rather than start from scratch, AASHTO cited the well-developed provisions in Chapter 17 of ACI 318,[2] with some exceptions. Anderson was also instrumental in helping to educate the bridge community in 2020 through a series of webinars and articles. Anderson recalls, "Sufficient use of anchorages necessitated the introduction of Article 5.13, and PCI wanted to be in the forefront in educating the bridge sector regarding the 'new' provisions." He also says, "AASHTO Article 5.13 is good for the industry and provides established design methodologies and quality control for cast-in anchor bolts and post-installed anchors in pier caps and bridge

A partial collapse at the Government Center garage during demolition, directly over the Haymarket Station tunnel in downtown Boston, Mass., halted subway service. The Massachusetts Bay Transportation Authority called on Simpson Gumpertz & Heger to evaluate the more than 120-year-old tunnel structure. SGH responded quickly, performing field observations and engineering analyses. Subway service was restored two weeks later. Photos: Simpson Gumpertz & Heger.



railings, sign structures, and guide rail attachments anchored into concrete." (See the four-part series in the Summer 2020, Fall 2020, Winter 2021, and Spring 2021 issues of *ASPIRE*® for the provisions of the AASHTO LRFD specifications related to concrete anchors.)

Recently, Anderson and others in the anchorage community have been assisting the AASHTO Committee on Bridges and Structures, Subcommittees T-4 (Construction) and T-10 (Concrete Design), with construction and installation phase issues, including determining the appropriate methods of field inspection when using post-installed anchors.

Boston Projects

SGH has been involved in numerous projects in downtown Boston. Following the 2022 collapse of a portion of the Government Center garage during planned demolition, the Massachusetts Bay Transportation Authority (MBTA) called SGH to help. The firm was recognized for their rapid response to determine the impact of the collapse on the Haymarket Station tunnel, located directly below the parking structure. SGH identified damage caused by the collapse and analyzed the impact effects on the tunnel carrying the MBTA's Green and Orange subway lines.

More recently, SGH worked with the MBTA to evaluate, test, and retrofit the rail attachments to the concrete slab sections in a downtown Boston tunnel. The assessment included evaluating the conditions of the mainline track system, including rail-fastening assemblies such as direct fixation fasteners and anchor studs in the cast-in-place slabs.

Washington State Route 520 Floating Bridge

Infrastructure and transportation systems are a critical sector for SGH. The firm works with owners and project teams to provide a wide range of engineering and code consulting services for new construction, evaluation, and rehabilitation projects for buried structures, tanks and pipelines, dams, airports, parking structures, pedestrian and vehicular bridges, and marine infrastructure. Their portfolio contains unique and challenging projects such as the world's longest floating bridge located in Seattle, Wash.

With a length of more than 7700 ft, the new State Route 520 Floating Bridge connecting Seattle and Bellevue, Wash., achieved a Guinness World Record for the longest floating bridge. The structure, completed in 2016, uses 77 precast, post-tensioned concrete floating pontoons joined together to support an elevated roadway above the pontoons. The pontoons are anchored with cables to the lakebed of Lake Washington.

Working with the joint venture of Kiewit, General Construction, and Manson Construction for the Washington State Department of Transportation, SGH performed specialty engineering tasks for construction engineering of the new bridge and served as engineer of record for the decommissioning of the original bridge.

According to Sam Yao, senior principal at SGH, during construction of the new bridge, SGH designed cable-anchor test frames used to evaluate the structural integrity of anchor cables, provided value engineering for the floating pontoon assembly, and designed the mooring facilities and fenders for berthing large concrete floating pontoons and construction vessels.

Decommissioning the original bridge was complicated by the retrofits, ballast modifications, and external post-tensioning along the entire length of the bridge. Errors during the removal work could have damaged the new floating bridge and its anchor cables. SGH performed a comprehensive engineering analysis to ensure that the original floating bridge could be safely disassembled and removed, including structural safety evaluation and floating stability analyses for ballasting, towing, mooring, assembly, and separation of floating pontoons. They also designed heavy lifts using floating derrick cranes to install and remove the bridge deck panels, girders, and columns. The bridge was successfully decommissioned, and the pontoons were repurposed as docks and artificial reefs. (For more on the State Route 520 Floating Bridge, see the Spring 2016 issue of *ASPIRE*.)

Governor Mario M. Cuomo Bridge

SGH performs a wide range of construction-related services, including the construction materials and operations side of a project. "We are structural engineers by training, but we also work with construction materials to solve problems," says Sherman.

"We are structural engineers by training, but we also work with construction materials to solve problems."

For the construction of the Governor Mario M. Cuomo Bridge connecting New Jersey and New York, which was fully

History of Simpson Gumpertz & Heger

Three innovators, Howard Simpson, Werner Gumpertz, and Frank Heger, founded Simpson Gumpertz & Heger (SGH) in 1956. They were professors at the Massachusetts Institute of Technology and renowned engineers, who used their passion and expertise to establish the guiding philosophies for SGH, which are still relevant today. "They possessed an unwavering commitment to excellence and integrity—and the trio dedicated their careers to perpetuating this culture," says Dominic Kelly, senior principal at SGH.

Each of the three founders had a specific area of expertise important to formulating the firm's three-pronged approach to engineering. Simpson led the structural mechanics group, Gumpertz oversaw the building technology group, and Heger directed the structural engineering group. "As SGH grew, so did our expertise in each of these areas, as team members were encouraged to advance their skills." says Kelly. "Today, SGH has five core services, and dozens of specialized capabilities."

The firm is nationally recognized as an expert on the causes of structural failure. For example, SGH was hired by the National Institute of Standards and Technology to investigate the collapse of the World Trade Center in New York City and assess the towers' structural response to impact damage and fire after the September 11, 2001, attacks.

On the Washington State Route 520 floating bridge project, Simpson Gumpertz & Heger served as the structural and marine engineer, as well as the engineer of record for many critical tasks. This epic 7700-ft-long structure crossing Lake Washington uses post-tensioned, precast concrete pontoons (360 × 75 × 28 ft) to support an elevated roadway. Photo: Simpson Gumpertz & Heger.

opened to traffic in 2018, SGH helped the precaster maximize the efficiency of concrete production while minimizing rejections and delays, all while meeting the strict project requirements. "We frequently collaborate with contractors and precasters," says Sherman. "On this large project we partnered with Unistress Corporation, one of four companies that supplied precast concrete products to the Tappan Zee Constructors joint venture."

Unistress was responsible for manufacturing precast concrete bridge deck panels and collaborated with SGH on the fabrication and production of the panels to meet the rigorous durability requirements specified by the New York State Thruway Authority. SGH helped the Unistress team produce 6000 full-depth deck panels efficiently and optimize the mixture proportions to meet the goal of a 100-year service life.

According to Brett Holland, senior project manager at SGH, it was a challenge to develop concrete mixture proportions that met the durability requirements while consistently maintaining the workability and constructability of the concrete. In addition to serving as liaison for engineering, production, and the owner, SGH performed special laboratory testing outside of the capabilities of the precaster's own quality-control laboratory. These tests included chloride permeability, resistance to freezing and thawing, shrinkage, and alkali-silica-reaction mitigation for the specialty concrete. SGH petrographers also monitored air entrainment and the air-void system of the concrete.

Working together, SGH and Unistress fine-tuned the mixture, which contained slag cement, fly ash, and silica fume, for production at Unistress's existing facility, as well as a temporary casting bed specifically dedicated for the megaproject. The typical precast concrete deck panels for this bridge are 45 ft long, 12 ft wide, and 11 in. thick, and weigh 74,000 lb. However, many panels are biplanar to accommodate variable roadway crown lines.

Casting the precast concrete deck panels was no small feat, but it was only a small part of the massive bridge project. The project involved 6 linear miles of bridge, which included approach viaducts and cable-stayed structures. The project used a vast quantity of structural precast concrete components, including pile caps, pier caps, deck panels, and crossbeams between its iconic towers.

Lightweight Solutions

When designers and precasters incorporate larger components and faster construction into projects, they often prefer high-strength structural lightweight concrete to avoid the possible complications of shipping, transporting, and lifting that can be associated with normalweight concrete. When project stakeholders are unfamiliar with the design and production of high-strength lightweight concrete, project collaboration is needed earlier than usual, with transparency and excellent communication between the project partners. SGH is often behind the scenes supporting precasters in this collaboration, helping the design and production teams better understand creep, shrinkage, resistance to freezing and thawing, and production aspects of high-strength lightweight concrete, all of which differ from the qualities of conventional concrete.

SGH has a long history of playing prominent engineering roles in design, investigation, and rehabilitation projects. The company's influence has played an important part in propelling SGH into the top 200 design firms in the United States.

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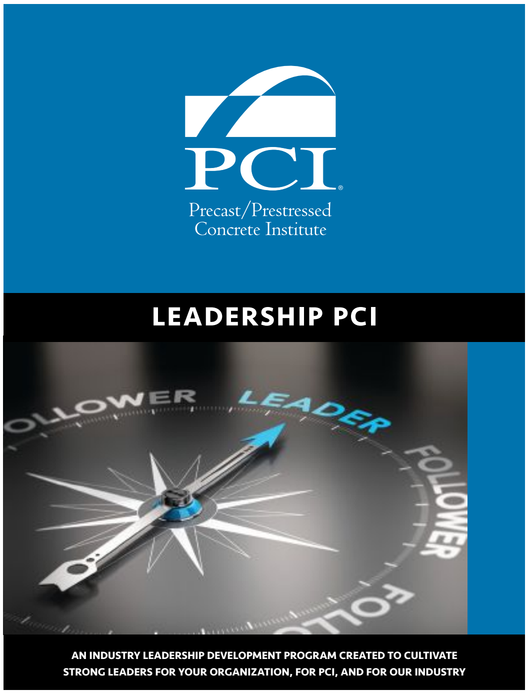
Leadership and Engagement Are Needed for Industry Sustainability

by Colin Van Kampen, EnCon Colorado



Leadership PCI is an industry leadership development program created to cultivate strong leaders for PCI and for organizations in the industry. Figure: PCI.

If PCI's word of the year for 2023 was "EPD" (environmental product declaration), then 2024's will likely be "sustainability." Last year, one could not avoid the acronyms, webinars, educational sessions, and publications aimed at advancing the Body of Knowledge around our industry's EPDs and their looming impact. Competing industries are jumping on board the campaign that claims concrete is the absolute worst construction material ever conceived. (See the editorial in the Spring 2023 issue of *ASPIRE*® for more about this perception.) Promoting precast concrete's sustainability is an industry-wide challenge, and cradle-to-gate data are not particularly helpful. As a result, PCI recently developed a Sustainability Plan to unify the strategic direction of the institute by urging all PCI councils and committees toward sustainable practices, initiatives, and principles.

When I was preparing to attend the first Sustainability Initiative meeting this past November as chair of PCI's Membership Council, I was at a complete loss as to what we could offer the industry. The council's committees are all nontechnical, providing membership benefits to the industry. There is not much that the council could deliver to affect an EPD or life-cycle assessment. Good attendance at the aforementioned webinars had my mind so focused on the environmental arena of sustainability that I had lost perspective on an alternative view of sustainability: that our processes and our people must also be sustainable.

The COVID-19 pandemic was a challenging time for all industries worldwide. It is now accepted that many aspects of most work can be done from home. Precast and prestressed concrete products, however, cannot be made that way. Throughout the pandemic, we innovated as an industry. We spread out tasks, craved socialization, and endeavored to have interaction. I was delighted that many virtual-meeting attendees had a positive outlook and were eager to volunteer for tasks and take on new challenges.

Post-pandemic, with the resumption of in-person meetings and in-office work requirements, hybrid work environments, and a return to normal, nonsocially distanced life outside of work, I wonder if the old bad habits are returning. Recent committee meetings have had fewer volunteers, more awkward silences following a call for the formation of a task group, and more laptops on tables with keystrokes sounding the passing of time. With each PCI gathering, the pool of volunteers grows smaller, with the usual individuals eventually, reluctantly, taking on the work of the committee. With all the effort to market and advance the wonderful material that is concrete, I wonder if the effort to maintain energy and life in our industry is sustainable.

The professional pool will soon incorporate a generation of youth who might have experienced their high school or college years socially distant from their peers or entirely at home. Most members of the graduating class of 2023 started school in 2019 and were affected by social distancing and virtual learning requirements before the publication of their school yearbooks. We all digest new knowledge daily via various educational and social media platforms, and in-home education is not a new or failed concept. However, there will soon be a flood of people who expect shorter work weeks, hybrid environments, soft deadlines, and relaxed requirements—all with sound environmental practices and stewardship—entering the world as young professionals. Are our production facilities, committee meetings, and industry processes ready for these individuals?

While commuting to work, frantic as to what to offer the Sustainability Initiative meeting, it hit me that the

Membership Council's contribution to industry sustainability is not in any way associated with the raw environmental data. Instead, the Membership Council has to double down on providing resources focused on the incorporation of people, cultures, perspectives, ideas, and leaders into the industry.

Currently, the Membership Council's most readily available contribution to the precast concrete industry is the Leadership PCI (LPCI) program. Recently resuscitated following pandemic impacts and the retirement of its long-standing facilitator, LPCI is now flourishing with many applicants, a new facilitator, and an updated curriculum. Participants are reporting positive results and experiences while establishing industry connections within the cohort. The program runs annually and lasts a full calendar year, starting at the annual PCI Convention and ending at the following convention.

Any PCI member can apply for this merit-based program. If an individual is selected, the return on the investment for the employer is instantaneous. Leadership training programs are everywhere. What sets LPCI apart is its direct connection to our industry. Envisioned by PCI Titans (individuals who have provided exceptional contributions and outstanding leadership and service in advancing the precast, prestressed concrete industry), LPCI is celebrating its 20th year. It is contained within our industry and steered by an LPCI alumni-member committee. There simply isn't a better avenue to build a precast concrete industry professional's career foundation. LPCI has an impressive industry retention rate, and many who participated in the first class of LPCI now run member companies, chair committees and councils, and serve on the PCI Board of Directors and Executive Committee.

A second contribution to professional improvement for PCI members is currently being developed by the LPCI Committee. Leadership, like any other skill, requires constant adaptation and development. For some time, the LPCI committee recognized an industry need for a second-tier program. Whereas the existing program turns young employees into managers, a second-tier program will turn managers into executives. Currently, the program facilitator is developing content and a curriculum that, if approved for implementation by the LPCI Committee, could become available in 2025.

For 70 years, PCI has flourished on the exchange of ideas, knowledge, and experiences. With the data-based challenges our industry faces with the implementation of EPDs and environmental sustainability requirements, it is the people in our industry who will set us apart from the other building-product industries. However, those people must come from somewhere, and they will crave a nurturing environment for their professional development. They must all see a path toward professional growth, accomplishment, and advancement that includes environmental stewardship. Without such embedded opportunity, the goal of sustaining our life force of industry-committed people who will join task groups and advance our committee agendas and therefore our Body of Knowledge would be unattainable.

We must never overlook the development of our future leaders.

From a broad, diverse pool of people will emerge those willing and skilled to lead. Not everyone is destined to be a leader. But a good leader can come from anywhere and be anyone. As much as we crunch the EPD numbers and innovate safer and more eco-friendly materials for our production needs, we must also never overlook the development of our future leaders. Our eyes must always be open to identify people who show flashes of leadership and initiative, however brief or seemingly inconsequential, and we must mark those individuals for leadership growth, mentorship, and development. They are as much a part of our Sustainability Initiative as our raw materials. A

Expansion of the Buy America Requirements for Highway Bridge Projects

by Dr. Timothy R. Wyatt, Esquire, Conner Gwyn Schenck PLLC

As covered in articles in the Fall 2020 and Fall 2022 issues of *ASPIRE*®, a long-standing "Buy America" statute codified at 23 U.S.C. §313 nominally requires almost all steel, iron, and manufactured products used on projects funded (or assisted) by the Federal Highway Administration (FHWA) to be produced in the United States. However, ever since Congress first enacted the provision, FHWA has waived the domestic content requirement for *all* manufactured products other than steel and iron. FHWA permanently adopted its manufactured products waiver in 1983, and at the same time provided a much more limited *de minimis* (that is, almost insignificant) waiver for steel and iron, allowing foreign steel and iron to be used on a federally assisted project only where the cost does not exceed 0.1% of the contract price or $2500, whichever is greater. Accordingly, although almost all predominantly steel and iron products on FHWA-funded projects must be manufactured entirely within the United States, in practice, there have historically been no such requirements for any other materials.

That changed with the enactment of the Infrastructure Investment and Jobs Act (IIJA) in November 2021. Under the new "Build America, Buy America" (BABA) provision of the IIJA, Congress provided that almost all steel, iron, manufactured products, and construction materials used on federally assisted infrastructure projects must be produced in the United States. In April 2022, the White House Office of Management and Budget determined that "construction materials" referenced in the BABA include products consisting primarily of nonferrous metals, plastic and polymer-based products, glass, lumber, and drywall. Therefore, by differentiating between construction materials and manufactured products, the BABA effectively provides that the FHWA's long-standing manufactured products waiver does not apply to products made primarily of wood, glass, plastic, or metals other than steel or iron. To strictly comply with the BABA, products made of such materials must be produced in the United States to be incorporated into federally assisted projects.

In May 2022, the U.S. Department of Transportation issued a temporary general waiver for application of the new BABA construction materials requirement. However, that waiver expired in November 2022. The new BABA requirement for construction materials now applies to all federally assisted transportation infrastructure contracts executed on or after March 10, 2023.

In August 2023, FHWA provided some relief by issuing a new *de minimis* waiver for construction materials. Under this waiver, construction materials produced outside of the United States may be incorporated into federally assisted highway projects, provided that the cost of such products does not exceed 5% of the total cost of all materials and products incorporated into the project, with an upper bound of $1 million for the cost of foreign-sourced construction materials on any project.

This new *de minimis* waiver for construction materials offers a great deal of flexibility to project owners and contractors, permitting a significant volume of construction materials of foreign or unknown origin to be incorporated into federally assisted highway projects. Certainly, the new BABA *de minimis* budget of 5% (or $1 million) for foreign construction materials compares favorably to the historic *de minimis* budget of 0.1% (or $2500) for foreign steel and iron. However, to take advantage of this new waiver, project participants must undertake the administrative burden of separately tracking the cost of all project materials and of all construction materials incorporated into the project that were not produced in the United States.

As originally proposed in November 2022, the new *de minimis* waiver would have also applied to steel and iron, not just the new category of construction materials. However, in the face of opposition, primarily from steel manufacturers and organized labor, FHWA elected *not* to extend the new waiver to steel and iron, deciding instead to maintain its much more stringent 1983 *de minimis* waiver for steel and iron.

Also as originally proposed by FHWA in November 2022, the new waiver would have exempted some quantity of "miscellaneous minor components" of steel or iron products. As I wrote in the Fall 2022 issue of *ASPIRE*, FHWA has long struggled with how to address "miscellaneous" steel and iron products such as screws, nuts, bolts, and washers. FHWA has seemed unable to resolve the discrepancy between its stringent application of Buy America requirements for steel and iron on the one hand and its waiver of Buy America requirements for manufactured products that often contain a significant amount of steel and iron components on the other hand.

In August 2023, in response to public opposition, including from steel manufacturers and organized labor, FHWA elected once again to not issue the proposed waiver specifically for miscellaneous steel and iron components. Instead, FHWA indicated that miscellaneous steel and iron components are likely covered by existing waivers (such as the new *de minimis* waiver for construction materials, the long-standing *de minimis* waiver for steel and iron, and the long-standing manufactured products waiver).

This suggests that, notwithstanding the requirement that almost all steel and iron incorporated into federally assisted highway projects be manufactured in the United States, a significant amount of foreign steel and iron is undoubtedly being incorporated into such projects in the form of components of products subject to the manufactured products waiver. Following an adverse ruling by the U.S. District Court for the District of Columbia in December 2015, FHWA has declined to issue formal guidance regarding the extent to which miscellaneous steel and iron components such as nuts, bolts, washers, and screws must have domestic content. Consequently, it has been left to each FHWA Division to determine at the project level whether a given product is predominantly steel or iron, or else covered by the manufactured products waiver.

To see the latest updates or sign up for email notifications about the Buy America Program, visit: https://www.fhwa.dot.gov/construction/cqit/buyam.cfm Figure: iStock.

For concrete bridge projects, FHWA's failure to issue definitive guidance creates uncertainty regarding how the domestic content requirements apply to steel reinforcement. BABA confirms the long-standing FHWA practice that Buy America requirements do not apply to cement, sand, and stone aggregate. However, as I wrote in the Fall 2020 issue of *ASPIRE*, the treatment of steel reinforcement has long been the subject of controversy and confusion. There is long-standing authority requiring steel reinforcement installed at the jobsite to be domestic (subject to the stringent steel and iron requirement). However, a project-level FHWA Division determination that precast concrete products are "manufactured products," not predominantly steel or iron, would conceivably allow foreign steel reinforcement in the precast concrete to be incorporated into the project.

In an April 2023 letter to FHWA,[1] PCI and the National Precast Concrete Association asserted that precast concrete is a "manufactured product" for purposes of Buy America requirements. Although the letter conspicuously omitted any mention of steel reinforcement within precast concrete, it implies that precast concrete is subject to the manufactured products waiver, which would conceivably allow the use of foreign component materials (including steel reinforcement), as long as the precast concrete products are deemed by the local FHWA Division not to be "predominantly" steel or iron.

However, FHWA's manufactured products waiver may be short-lived. In March 2023, concurrent with its adoption of the new *de minimis* waiver for construction materials, FHWA formally solicited public comments on whether the manufactured products waiver should be discontinued or modified. BABA expressly discouraged the use of broad, general applicability waivers, such as the manufactured product waiver. As of this writing, FHWA has received more than 7500 comments in response to the solicitation, with many in favor of retaining the manufactured products waiver and many opposed. Although no action has been taken to date, it seems unlikely that the manufactured products waiver will continue in its current form. Given FHWA's issuance of the new *de minimis* waiver for construction materials, a new *de minimis* waiver for manufactured products could likewise be forthcoming, allowing some foreign manufactured products to be incorporated into federally assisted highway projects, on the condition that project participants actively track and limit the use of such products.

In summary, the Buy America requirements for highway and bridge projects continue to slowly but surely evolve in favor of expanded application to a broader range of materials. Relief in the form of *de minimis* waivers by FHWA enable projects to be constructed with some foreign content but impose administrative burdens on FHWA project owners and contractors to track and limit foreign content. With the new BABA requirements, FHWA project participants are now faced with domestic content requirements not just for steel and iron but also for construction materials that include other metals, wood, glass, plastic, or polymers. FHWA project participants should expect the Buy America requirements (and associated administrative burden) to continue to expand to most other manufactured products sooner rather than later.

Reference

1. Precast/Prestressed Concrete Institute and National Precast Concrete Association. 2023. "Comment regarding Docket No. FHWA-2022-0027, Review of General Applicability Waiver of Buy America Requirements for Manufactured Products." Posted April 16, 2023. https://www.regulations.gov/comment/FHWA-2022-0027-7222.

PERSPECTIVE

Building Bridges beyond Structures: Fostering Support and Encouragement within Our Industry

by Nyssa Beach, Colorado Department of Transportation

As an engineer in the transportation and structural engineering industry, I have traveled through many challenging and exciting projects on my career journey. When this path led to the first cast-in-place concrete segmental bridge for the state of New Mexico (see the Project article about U.S. Route 54 over the Canadian River in the Winter 2021 issue of *ASPIRE*®), I eagerly joined the design team and soaked up the opportunity to learn all I could about concrete segmental bridge design.

In 2016, I attended my first American Segmental Bridge Institute (ASBI) conference and immersed myself into this specialized world of structural design and construction. The first morning of the conference, I headed toward the convention center and asked for directions to ASBI. I was directed toward some signs, which led me to a meeting room. I stepped into the room and was momentarily amazed at the incredible representation of women at the ASBI conference—until I realized that I had been directed to the ASBI spouses' breakfast. I felt embarrassed and flustered, but a group of extremely kind women turned me around and pointed me in the right direction. I squared my shoulders and joined the other conference attendees with the thought that perhaps my involvement at ASBI could make a difference.

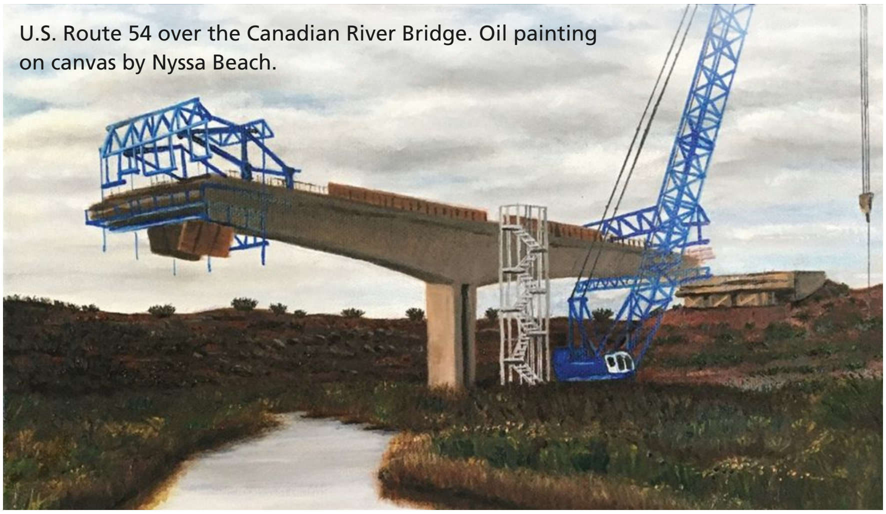
Like many others, I've had my moments of wondering if I belonged in engineering. Ultimately, I've been fortunate throughout my career to have wonderful mentors and supporters who have solidified my belief that I do belong, and that our industry excels at supporting people. Through the work we do and the teams that make this work happen, our inherently people-driven industry leaves a legacy beyond the structures we build, passing on collective knowledge to the next generation. I've found that mentorship is critical; it shapes the individuals who currently lead our engineering industry forward and those who will one day become leaders.

"In order to be a mentor, and an effective one, one must care. You must care," Maya Angelou states in one of my favorite quotes. "Know what you know and care about the person, care about what you know and care about the person you're sharing it with."

My mentors and supporters include the engineer just a year ahead of me at my first job who took me under her wing and pointed out which socks to wear during cold-weather bridge inspections, the supervisor who helped me identify and align key skills in myself that I couldn't see on my own, and even the coworker who kindly sympathized when I came to work as a new mom with baby spit-up dripping down my back. As we progress, it becomes our responsibility to ensure the success of future generations in this industry.

This responsibility felt more personal for me as I made a recent career shift from the private to the public sector. I got to immerse myself in not just the "what" but the "why" of projects by stepping into a role with the Colorado Department of Transportation as a resident engineer. My job now involves leading a team and orchestrating the development of diverse infrastructure projects in the Denver metro area. I represent my community from an owner's mentality on projects from the conceptual stage through design and construction, and with long-term asset management. For me, the best part of this role is connecting the collective knowledge and skills of our industry to solve problems and help communities.

Making this career leap required stepping outside of my comfort zone of structural technical design and



U.S. Route 54 over the Canadian River Bridge. Oil painting on canvas by Nyssa Beach.

Nyssa Beach and her daughters, Hannah and Maddie Beach, during the Women's Transportation Seminar Colorado Girl Scout Mobility Day Tour 2023. Photo: Women's Transportation Seminar Colorado.

taking a leadership role within project teams. The job involves managing all facets of infrastructure—coordinating technical issues, stakeholders, and community members—as well as working with our maintenance teams, construction staff, and the Federal Highway Administration. At this stage in my career, I felt confident in making this leap not only because of my own skills and experience but also from the solid foundation of support that I have within our industry. I hear time and time again, "This is a small industry." I have benefited from my involvement in professional organizations and the relationships I have formed working on projects, being part of teams, and sitting on committees. While I may not always know the answer, I know who to call, where to find training, and where to look to seek out different perspectives that can challenge my viewpoint. I'm well positioned to support others in this industry.

Each year in the fall, I help with a Women's Transportation Seminar Girl Scout Mobility Day in downtown Denver, Colo. The event is a wonderful, chaotic, giggly, walking tour of urban engineering, with civil engineers and planners serving as the girls' guides at each stop. The scouts learn to read a train schedule and ride the Denver Regional Transportation District light-rail trains, and we visit a transit-oriented development. They walk through blocks of the Denver Union Station in pairs for a blindfolded Americans with Disabilities Act activity, learn bike safety right next to the green-painted bike lanes, and scramble up to the platform of the Denver Millennium Bridge to "think like a bridge engineer!"

With my many years of experience designing, constructing, load-rating, and maintaining bridges, I'm their guide to all things bridges. I've done my "bridge talk" for more than 12 years now: while pregnant, with a baby strapped to my back, pregnant *and* with a toddler strapped on my back, with my kids toddling around between my legs, and, most recently, with my own two Girl Scouts as part of the tour group.

Before talking with the scouts about how many bridges there are in the United States (they're always shocked that it's more than 100), discussing how bridges are designed for loads (I've gotten the question: "So, would a bear attack be a 'load'?"), and challenging them to "think like a bridge engineer," I always share the following message: I think that being a good engineer doesn't necessarily require figuring things out easily, but it does involve not giving up on things that are hard and loving that feeling of solving the problem. And if you look different, think differently, and have a different background than others around you—great! Engineers can design and construct solutions to uplift our diverse world. We only do that truly well when our teams are as diverse as the communities we serve.

To me, it's important to pass along this message. I've shared it while working on STEM activities with the Girl Scouts, in school classrooms, college classrooms, with LBGTQ youth, and with minority and underrepresented organizations. I try to take this message with me to work every day and often tell it to my inner voice that pushes back each time I take a step forward in my career path. I belong in engineering, and I want to do my part to both improve the community around me and help this industry become an encouraging and supportive field.

Women's Transportation Seminar Colorado Girl Scout Mobility Day Tour 2023 at the Millennium Bridge in Denver. Photo: Women's Transportation Seminar Colorado.

PROJECT

North Split Interchange Reconstruction

Interstates 65 and 70 in Indianapolis

by C. Brian Slagle and Christine Lu, Janssen & Spaans Engineering

In downtown Indianapolis, Ind., Interstate 70 (I-70) and Interstate 65 (I-65) merge and overlap for just over two miles. The northern terminus of this interstate concurrency, where the routes separate into two independent roadways again, is locally known as the "North Split" and is part of the state's second busiest interchange. More than 214,000 vehicles per day constantly merge and weave throughout this system interchange, which also includes seven local entrance and exit ramps. The North Split reconstruction project was an investment to upgrade central Indiana's most congested interchange, improve safety, and showcase Indiana's unique identity. The project's largest flyover bridge (Bridge 34) displays the beauty of the Indianapolis skyline and demonstrates the thriving metropolitan image of Indiana's capital city.

Many of the existing bridges and roadways in the North Split were deteriorating and in need of repairs. Additionally, the existing interchange configuration was inefficient and not designed for the current volume of traffic. The Indiana Department of Transportation (INDOT) saw the opportunity to improve safety and operations with a project that completely reconstructed the

North Split interchange where Interstates 65 and 70 weave, with Indianapolis, Ind., in the background. Photo: Indiana Department of Transportation.

profile

INTERSTATE 65/INTERSTATE 70 NORTH SPLIT INTERCHANGE / INDIANAPOLIS, INDIANA

BRIDGE DESIGN ENGINEER: Janssen & Spaans Engineering Inc., Indianapolis, Ind.

Other Consultants: Bridge design services: Butler, Fairman & Seufert, Indianapolis, Ind., and Ciorba Group, Chicago, Ill.

PRIME CONTRACTOR: Superior Construction Co. Inc., Portage, Ind.

CONCRETE SUPPLIER: Irving Materials Inc., Greenfield, Ind.

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

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International USA Inc., Bolingbrook, Ill.

To provide a 16-ft 9-in. underpass clearance, an intermediate straddle bent was designed with precast, prestressed concrete beam ends built integral to the cast-in-place concrete, post-tensioned bent cap. Photo: Janssen & Spaans Engineering.

interchange for the first time since 1976.

To expedite delivery and ensure a cost-effective project, INDOT decided to use a design-build best-value procurement process. In October 2019, INDOT issued the final request for proposals to three short-listed, prequalified design-build teams. During the proposal period, INDOT encouraged project innovation by allowing teams to submit alternative technical concepts (ATCs). Each team could submit confidential ATCs to solicit feedback and acceptance from INDOT. Approved ATCs were permitted to be incorporated into the teams' proposed designs and priced accordingly.

INDOT evaluated the proposals on a 100-point best-value scale. The cost represented 65 points of the total score, and the technical proposal represented 35 points of the total score. The technical proposal score was based on the proposer's schedule, design, and project management plan. On March 10, 2020, all three teams submitted their proposals. The proposal with the highest score offered the design and construction of the project for approximately $316 million.

The post-bid start of this project coincided with the onset of the COVID-19 pandemic, and all parties quickly became familiar with the force majeure contract clause. Remote work started, materials became scarce or unavailable, workers were in short supply, and everyone soon realized it would not be possible to meet the substantial completion date of November 2022. In total, the pandemic added more than $90 million to the construction costs and delayed substantial completion to May 2023.

The design of the North Split interchange reduced the footprint from the original interchange. This aspect of the design, along with the commitment to not add any additional lanes within the project limits, needed approval from the residents and stakeholders. The project demolished 32 existing bridges and replaced them with 42 new bridges. Additionally, three bridges received overlays and three others involved deck replacements with superstructure widenings. In total, more than 388 prestressed concrete girders were incorporated into the new bridges. The work also included upgrading the existing pavement of the corridor to continuously reinforced concrete pavement.

Bridges that Will Last

Considering the importance of this interchange, its location in downtown Indianapolis, and the high volume of vehicles per day, INDOT wanted the

Bridge 34 under construction. On a portion of Bridge 34, a section of curved alignment is accomplished by kinking the beam layout at the supports, which include architecturally enhanced columns and hammerhead bent caps. Photo: Janssen & Spaans Engineering.

INDIANA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Bearings: D. S. Brown, North Baltimore, Ohio; formwork: PERI Formwork Systems Inc., Indianapolis, Ind.; stay-in-place deck forms: L. B. Foster, Pittsburgh, Pa.

BRIDGE DESCRIPTION: 42 new bridges, 3 deck replacements with widenings, and 3 bridge deck overlays; Bridge 34 is a nine-span bridge with a total structure length of 1236 ft and span lengths that vary from 98 to 164 ft; Bridge 17 has two 176.5-ft precast, prestressed concrete spans at a 74-degree skew supported by an intermediate straddle bent

STRUCTURAL COMPONENTS: 388 prestressed concrete bulb-tee girders—including 72-in.-deep beams for Bridge 34 and 84-in.-deep beams for Bridge 17; 9 million lb of structural reinforcement; 34,000 yd^3 of concrete; and one cast-in-place concrete, post-tensioned straddle bent reconstruction project with its extended closures to occur only once, and not to have to touch the interchange again for many years. To meet this goal, INDOT incorporated technical provisions in the contract documents that would lead to the construction of durable, long-lasting bridges using elements that extend the design life of components and minimize maintenance cycles.

In all bridges, the deck is the first line of defense against deterioration caused by traffic and the elements. INDOT's response to this issue included a two-pronged approach to the material selection for the decks. All new decks were specified to be a minimum 7.5-in.-thick alternate Class C concrete plus a 1.5-in.-thick, very-early-strength latex-modified concrete overlay. The alternate Class C concrete was designed to improve bond strength, compressive strength, and abrasion resistance when compared with the normal Class C concrete. These improvements were accomplished by adding either 3% silica fume by weight of cementitious material to the mixture or by substituting 30% ground granulated blast-furnace slag based on the required cement content

A component of the project's aesthetics and enhancements implementation plan is the placement of precast concrete corner monuments ranging from 22 to 38 ft in height. Here, a decorative monument is located adjacent to mechanically stabilized earth abutment walls. Photo: Janssen & Spaans Engineering.

in the mixture and including a water-reducing admixture with the amount of water adjusted accordingly. To reinforce the decks, stainless steel reinforcing bars were required. The stainless steel reinforcing bar requirement also extended to the integral diaphragms at the end bents, intermediate pier diaphragms, and approach slab tie bars extending into the deck.

Typically, INDOT limits the maximum design 28-day concrete strength to 8000 psi for prestressed concrete beam design. For this project, INDOT developed a special provision for precast, prestressed high-strength concrete components that permitted a maximum design 28-day strength of 10,000 psi and allowed a transfer strength of up to 8000 psi. All reinforcing bars protruding from the beams into the deck were epoxy coated, and the bars completely contained in the beams were plain reinforcing steel. All steel embed plates and steel diaphragms were Grade 50 and galvanized.

Deck joints are typically another high-maintenance item, and INDOT therefore specified that they would be eliminated at all end bents on this project. If thermal movements could not be otherwise accommodated, deck joints were permitted but they had to be placed as close to a vertical curve high point as possible. To accommodate thermal movements at the end bents, INDOT specified the use of integral or semi-integral end bents. Both types of end bents eliminate the joint and allow thermal movements to be accommodated at the end of the approach slab. Semi-integral end bents were used if the criteria for integral could not be met due to the combination of skew and expansion length of the unit. Semi-integral bents require the use of an expansion bearing. For this project, INDOT implemented a new semi-integral detail that provides a seat where temporary jacks can be placed, which will make it easier to replace bearings in the future.

The North Split Project map. Figure: Indiana Department of Transportation.

Bridge 34

The largest bridge on the project was the I-65 southbound ramp to the I-70 eastbound structure, otherwise known as Bridge 34. This is a nine-span bridge crossing over a local street and five other ramps. The total structure length is 1236 ft traversing an alignment that starts in a tangent and transitions to a horizontal curve. The span lengths on this bridge vary from 98 to 164 ft, and the bridge varies in width from 63 ft to 67 ft 2 in.

The superstructure consists of seven lines of BT 72 × 49 beams—prestressed concrete bulb-tee beams that are 6 ft tall, with a bottom flange width of 3 ft 4 in. and a top flange width of 4 ft 1 in. The beams have up to sixty-five 0.6-in.-diameter prestressing strands and include both harped and debonded strands. The maximum design concrete strength of 10,000 psi was used to take full advantage of the high-strength concrete. The heaviest Bridge 34 beam weighed approximately 202,200 lb.

The beams were designed as simple spans for all loads placed before the deck has cured. The design considered the beam

Aerial view of the North Split Project north of downtown Indianapolis, Ind., where Interstates 70 and 65, including local access and exit ramps, intermingle. Photo: Indiana Department of Transportation.

continuous for all live loads and dead loads placed on the composite deck. The beams were made continuous with protruding strands in the concrete closure pours between the ends and negative-moment reinforcement in the deck. To accommodate the portions of curved alignment, the beam layout was kinked at the intermediate pier support points.

The piers supporting the beams used 63-ft-long, variable-depth (8- to 12-ft tall) hammerhead caps supported by architecturally shaped columns. The pier heights range from 36 to 61 ft, with the two tallest piers supporting a span over two levels of traffic. The piers are geometrically complex due to the curved alignment and architectural features. A custom, prefabricated formwork system was used for the columns and massive hammerhead pier caps to increase the safety and efficiency of the construction.

Bridge 17

The bridge with the longest span in the project was the I-65 northbound bridge over the I-70 eastbound entrance ramp, known as Bridge 17. This bridge spans the underpass ramp at a 74-degree skew resulting in two 176.5-ft precast, prestressed concrete spans supported by a massive intermediate straddle bent.

The 176.5-ft spans consist of six 84-in.-tall precast, prestressed concrete beams. These are currently the longest and heaviest individual prestressed concrete beams that have been used in Indiana, with lengths varyng from 175 to 178.5 ft, and weights up to 234,900 lb. A high level of attention to detail and extensive analysis were needed to ensure that the beams were not only built to support final service loads but also detailed and built for safe transport and erection. The beams included temporary top strands to resist handling and shipping loadings.

Given the limited vertical clearances under the bridge, the intermediate straddle bent was designed as a 9 × 9 ft cast-in-place concrete, post-tensioned bent cap with precast, prestressed concrete beam ends from the adjacent spans built integral to the cap. The cap spans 75 ft from center of bearing to center of bearing, is supported by two 10-ft 4-in. × 8-ft 4-in. architecturally shaped columns, and provides a 16-ft 9-in. underpass clearance. Limited clearance under the beam ends embedded in the integral cap was a challenge in designing the post-tensioning system. The 1.13 million-lb bent cap supporting the 45-ft-wide bridge contained 14 post-tensioned tendons, with each tendon containing nineteen 0.6-in.-diameter strands. The bent cap concrete design strength was 6000 psi. The beams were independently supported by falsework towers to provide stability while the integral cap was constructed.

Aesthetics

In addition to improving the overall traffic connectivity and flow of the interchange, the North Split project aimed to integrate the new infrastructure into surrounding neighborhoods by incorporating various architectural and landscaping enhancements.

One of the main architectural features of the project is the corner precast concrete decorative monuments located at the base of the bridges at the local street crossings. The monuments range in height from 22 to 38 ft. They were precast off site and erected adjacent to the interfaces of the end bents and mechanically stabilized earth walls. The cast-in-place concrete footings were designed to support each monument's weight, with an anchor connection between the bridge end bent and the monument designed to resist the monument's lateral load.

The piers and walls (including mechanically stabilized earth walls and sound barriers) within the project were detailed in accordance with the project's aesthetics and enhancements implementation plan. The design features fluting of pier columns, trapezoidal-shaped pier caps, granite-emulating formliners, and various lighting enhancements. The plan also detailed the project's color scheme, surfacing details, and landscaping details.

Conclusion

On May 1, 2023, all lanes and movements on the project were open to traffic. The project continues to wind down with the completion of aesthetic enhancements and landscaping. All stakeholders can now enjoy this upgraded interchange that removed bottlenecks and improved traffic flow, which was accomplished without added travel lanes by the elimination of problematic weaves.

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C. Brian Slagle is vice president and Christine M. Lu is senior project manager with Janssen & Spaans Engineering in Indianapolis, Ind.

PROJECT

West Sammamish River Bridge

City of Kenmore, Washington

by Kevin S. Kim and Hana D'Acci, Jacobs, and John Vicente, City of Kenmore

In August 2022, the city of Kenmore, Wash., celebrated the opening of a new bridge to replace the structurally vulnerable southbound bridge carrying 68th Avenue NE over the Sammamish River. Located at the north end of Lake Washington, West Sammamish River Bridge is a major arterial, carrying about 20,000 vehicles per day. The original bridge was built in 1938 with cast-in-place concrete box girders. During a routine inspection in 2013, crews discovered cracks in the bridge's concrete box girder, as well as scour concerns around the timber cofferdams surrounding the in-water bridge piers. The City of Kenmore hired a consultant engineer to investigate these issues and, later, to lead replacement efforts for the aging bridge. The parallel East Sammamish River bridge, which was built in the 1960s and carries northbound traffic, remains in place because it did not exhibit the same deterioration as the much older southbound structure.

Aerial view of the construction site showing the precast, prestressed concrete tub girder erection. Photo: City of Kenmore.

The new West Sammamish River Bridge is a 600-ft-long, five-span structure with precast, prestressed concrete tub girders and an 8-in.-thick minimum cast-in-place concrete deck. The typical bridge section carries two 10-ft-wide lanes of southbound traffic and a 16-ft-wide multiuse path for bicyclists and pedestrians. The superstructure is supported by 5 × 4 ft, rectangular cast-in-place columns on 8-ft-diameter drilled shafts. The bridge is enhanced by an approximately 11-ft-wide, 32-ft-long, semi-oval overlook supported by a concrete cantilevered crossbeam at pier 3. Other improvements include a concrete bench on the overlook with a series of historical oars serving as both public art and separation from the multiuse path, architectural railings, LED lighting, and new landscaping along the corridor.

Key Project Challenges

Replacing the bridge at its original location posed many challenges, including a limited construction staging area, a brief window for in-water construction, and a need to maintain two lanes of traffic in each direction throughout construction. During preliminary design, the team developed a

profile

WEST SAMMAMISH RIVER BRIDGE / KENMORE, WASHINGTON

BRIDGE DESIGN ENGINEER: Jacobs, Bellevue, Wash.

PRIME CONTRACTOR: Ceccanti Inc., Tacoma, Wash.

CONCRETE SUPPLIER: CalPortland, Kenmore, Wash.

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

OTHER MATERIAL SUPPLIERS: Seismic isolation bearings and elastomeric bearings: D. S. Brown, North Baltimore, Ohio; geofoam blocks: FMI-EPS LLC, Post Falls, Idaho; ClearCast forms: TrueTech Bridge, Raleigh, N.C.

detailed plan to address those challenges as part of the biological assessment. The schedule included staged demolition and construction sequences that allowed two lanes of traffic to be maintained in each direction throughout construction. Additionally, the team proposed building a temporary trestle during the limited window for in-water work on the downstream side of the existing bridge. Some of the notable project challenges included the following.

- **Protecting the environment during the project.** Environmental stewardship was an important priority for the city as the team undertook this project. Planning, permitting, and constructing the new bridge presented numerous challenges to the environmental team. Because the cracks noted in the concrete girders and settlement of the existing bridge indicated a need for prompt action, the team set out to expedite the environmental permitting process. Challenges associated with the project included accommodating endangered aquatic species and adjacent recreational facilities. The team coordinated with 20 state and federal agencies to obtain 18 permits and approvals—nearly every permit possible in Washington. There were also strict in-water work requirements, including no more than 45 days of work each year in July and August. The environmental team collaborated with the contractor to support an aggressive three-year construction schedule, ensuring environmental compliance while keeping the project moving forward.

- **Minimizing public inconvenience during construction and protecting lives and property.** Kenmore is an active and vibrant community.

In two cases, removal of the existing concrete foundation required that sections be cut in half. Photo: City of Kenmore.

In addition to serving as a vital transportation route for people traveling to and through the area, the bridge is surrounded by popular recreation attractions such as a boat launching park, recreational boating on the Sammamish River, Rhododendron Park, Burke-Gilman Trail, and Inglewood Golf Course. Traffic was a frequent concern among community members. The original plan was to maintain two lanes of southbound traffic at all times by constructing the bridge in stages. However, when construction began in 2020, the traffic volume dropped significantly because of the COVID-19 pandemic. As a result, the city allowed the West Sammamish River bridge to be constructed under full closure while one lane of traffic was maintained in each direction on the East Sammamish River Bridge. With the full closure of the West Sammamish Bridge, the contractor was able to expedite construction within two in-water seasons instead of three. The design team provided

Before the deck is placed, the formwork is supported by the precast, prestressed concrete tub girders. The tub-girder shape is visually compatible with the existing northbound box-girder bridge. Photo: Jacobs.

CITY OF KENMORE, OWNER

BRIDGE DESCRIPTION: 600-ft-long, 45-ft-wide, five-span bridge over the Sammamish River located at the north end of Lake Washington in the Seattle, Wash., area. The bridge carries about 20,000 vehicles per day and provides access to a major regional trail system, Burke-Gilman Trail, for bicyclists and pedestrians with a 16-ft-wide multiuse path.

STRUCTURAL COMPONENTS: Twenty WSDOT UF60G5 precast, prestressed concrete tub girders, 110 to 140 ft long, supported on seismic isolation bearings, 8-in.-thick cast-in-place concrete deck, cast-in-place concrete pier caps, 5 × 4 ft rectangular concrete columns, and 8-ft-diameter drilled shafts

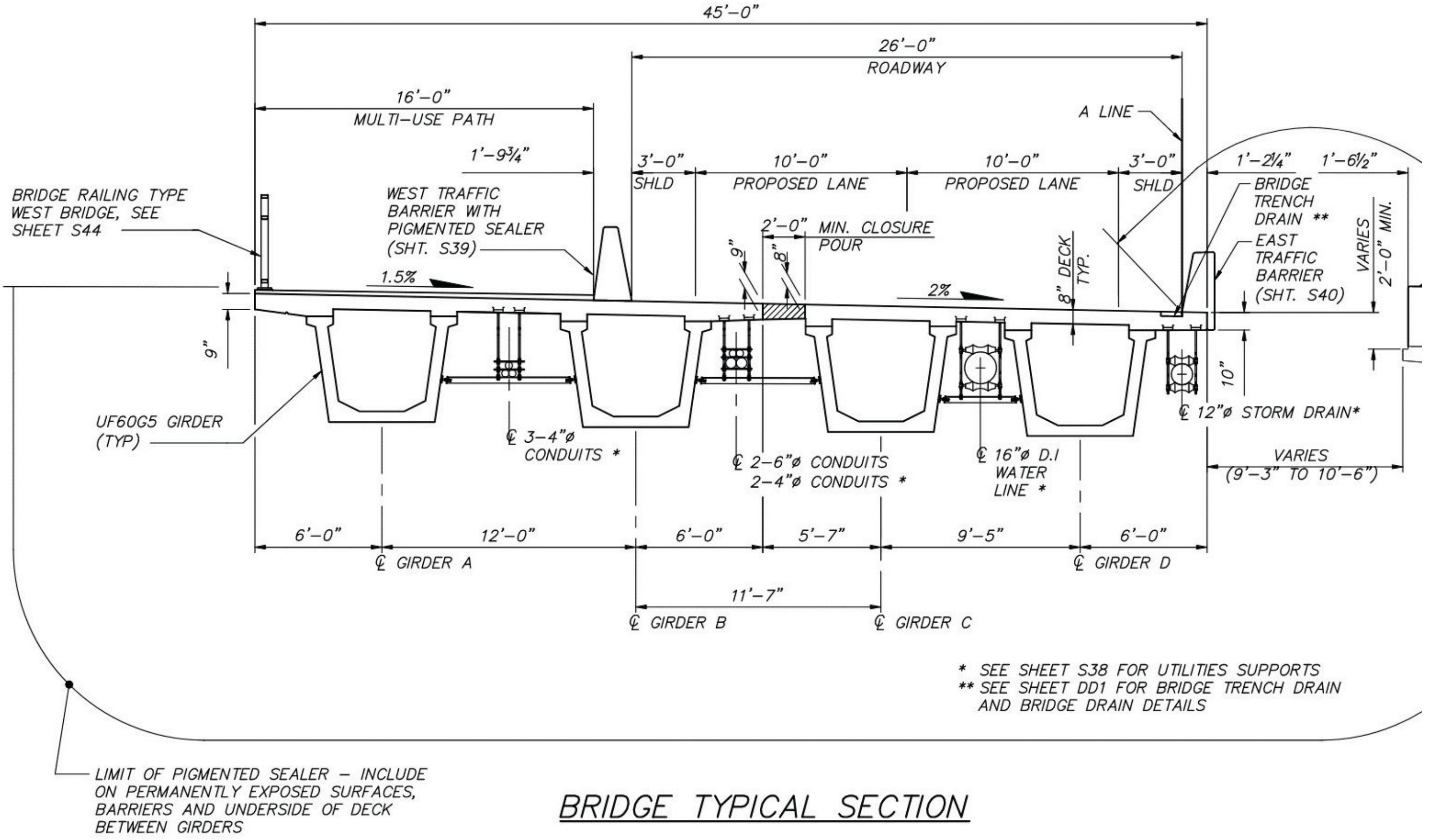
BRIDGE CONSTRUCTION COST: Approximately \$20 million (\$650/ft^2)

AWARD: 2023 American Council of Engineering Companies Washington Design Excellence Award for Complexity consistent, detailed information about closures and other impacts in advance, using newsletters, postcards, and email updates, in addition to website and social media posts. Pedestrians and bicyclists also rely on the bridge, and a popular boat launch in the river was temporarily affected. The design consultant worked with the city and community to understand the needs of all users and then proactively worked with local contractors to incorporate strategies into the plan set for advancing necessary work while minimizing disruptions.

Installing one of the precast, prestressed concrete tub girders. The typical girder is 110 ft long and weighs 165 kip. Photo: Jacobs.

- **Removing existing bridge foundations.** As-built plans of the original 1938 bridge were a close match for what was discovered in the field, but removing the structures proved to be extremely difficult. A local specialty contractor pumped the sediment from below the concrete foundations and exposed the supporting timber piles. Once the piles were exposed, divers threaded lifting cables underneath the foundation sections. While the cables were suspended from a crane, the divers used underwater chainsaws to cut the existing pilings. When the pilings were all cut, the crane lifted the existing concrete foundation out of the river, which was dangerous and time-consuming work. The four foundations weighed between 140,000 and 200,000 lb each. Two of the foundations were so heavy that they exceeded the capacity of the cranes and could not be lifted without first being cut in half vertically. The contractor worked extended hours during the in-water work window to complete the foundation removal.

The bridge typical section. The structure carries two 10-ft-wide lanes of southbound traffic and a 16-ft-wide multiuse path for bicyclists and pedestrians. Figure: Jacobs.



At the roadway approaches, geofoam blocks are placed over traditional gravel materials to mitigate settlement of the highly compressible peat layers. Photo: City of Kenmore.

Seismic isolation bearings—rubber bearings with lead cores —reduce the seismic demand on the concrete columns and foundation. Great blue herons are featured on the pier columns because the Sammamish River is a major habitat for the species. Photo: Jacobs.

Accelerated Bridge Construction

Because in-water work had to be completed during a narrow window while traffic was maintained on the busy corridor, the team applied the following accelerated bridge construction techniques to expedite construction.

- **Precast concrete girders compatible with the existing structure.** The northbound East Sammamish River Bridge is a five-span cast-in-place concrete box-girder bridge. To ensure that the new southbound West Sammamish River Bridge structure would be visually compatible with the existing bridge, the team decided to use precast concrete "tub-shaped" girders (WSDOT UF60G5) and the same span arrangement as the remaining northbound bridge. As such, two girder lengths were used on the project; span 2 had a girder length of 140 ft with a weight of 210 kip, and the other four spans had 110-ft-long girders weighing 165 kip. This aspect of the design not only expedited construction but also minimized impacts on environmentally sensitive areas.
- **Stay-in-place forms for bridge deck construction.** To expedite construction and minimize traffic disruptions, the design team used a transparent, acrylic stay-in-place form to construct the cast-in-place bridge deck. This type of form is not widely used in Washington state due to its higher material cost but was a good choice in this instance because it saved construction time and reduced the effort needed to set up and strip temporary formwork. This approach also provided safety benefits for construction workers. The transparent material allows for

The completed bridge's multiuse path and gathering overlook. Photo: Jacobs.

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

Simpler is often better. The West Sammamish River Bridge is a great example of this principle. There, keeping things simple was a necessity, not a choice. The project faced major traffic maintenance and environmental constraints, and simplicity made it easier to deal with them. The parallel East Sammamish River Bridge provided a helpful model of a concrete box-girder bridge from which to start, and the availability of standard precast concrete box girders (WSDOT UF60G5) made building the bridge simpler still. All this simplicity paid off when the COVID-19 pandemic erupted.

The memorable aspect of this bridge is what the designer did with these simple elements. The key details are at the overlook at the midriver pier. Look at the ends of the pier cap: they are slanted at the same angle as the box girder webs. There was no need to insert a different angle. In addition, the concrete bracket supporting the overlook is a massive concrete shape that appears to be an extension of the similarly massive pier cap.

Finally, the nine vertical "oars" of the monument on the multiuse path provide a vertical element that further delineates the position and importance of the overlook. The lightweight and simply patterned pedestrian railing offers a transparent horizontal feature that doesn't compete with the visual prominence of the overlook or interfere with travelers' views from the bridge.

Overall, the new bridge offers an attractive background and setting for the popular recreational attractions surrounding it.

future inspection of the bottom of the bridge deck as required by the Washington State Department of Transportation.

- **Geofoam blocks to mitigate settlement.** The bridge corridor is underlain by highly compressible peat layers, which are prone to settlement. To mitigate long-term settlement due to new roadway approaches at each end of the bridge, the design team recommended using geofoam blocks for the roadway subgrade instead of gravel. The geofoam blocks are extremely lightweight but structurally adequate to support the roadway without inducing any long-term settlement along the corridor. Use of geofoam blocks over the traditional gravel materials substantially shortened the construction duration.

Seismic Resiliency

The previous bridge lasted more than 80 years, and the city wants the new bridge to serve the public for decades to come, with a minimum 75-year service life. To achieve that goal, the latest technology was used to account for climate change, seismic conditions, and the day-to-day needs of the structure over the long term. Given the earthquake risks at the bridge location, seismic resiliency was an important component of the work. To accommodate seismic design requirements for a 1000-year design seismic event and to reduce the seismic demand on the concrete columns and drilled shafts, the design team used seismic isolation bearings to support the bridge superstructure. Although seismic isolation bearings are typically used on complex structures or seismically vulnerable older bridges, the design team specified them for this structure because they are suited for the presence of liquefiable soil layers, which would cause lateral spreading, and for short column heights that could not withstand the seismic displacement demands. A rubber bearing with a lead core was selected for its cost effectiveness and ease of installation.

Conclusion

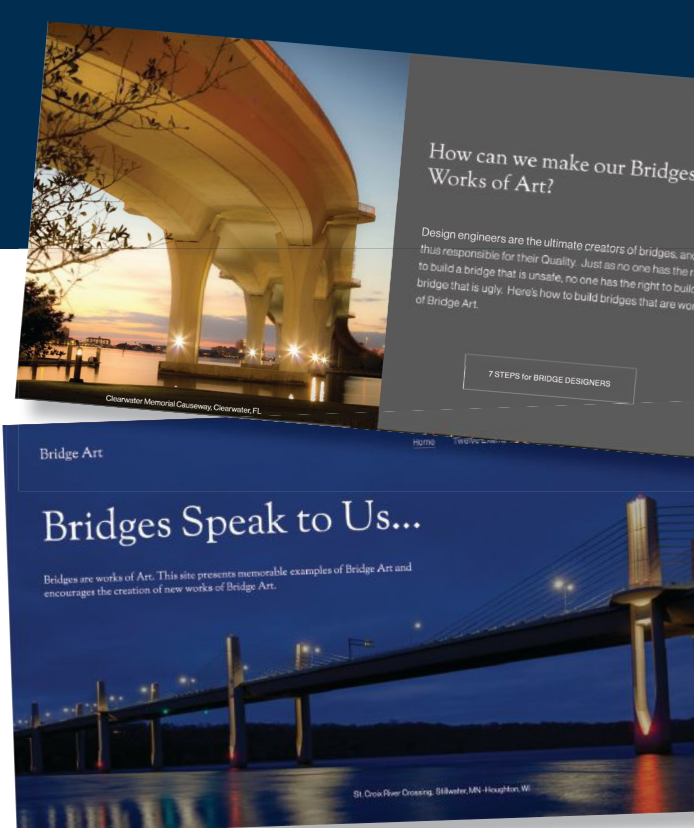
The team anticipated certain challenges but could not have anticipated the onset of a global pandemic. Despite the initial pandemic shutdown, followed by a lengthy concrete delivery drivers' strike in the area, the design team was able to revise the construction sequences, and make other changes that enabled the project to meet the original construction completion date of fall 2022..

The City of Kenmore wanted more than just a bridge. They wanted transportation solutions for all modes, and a better overall experience for users of this heavily traveled corridor. The result was a successful project that replaced a vital piece of the city's infrastructure, giving the community an improved experience as they travel through the area. The community and the team were excited to celebrate the bridge's on-time completion at a ribbon-cutting celebration in August 2022. A

Kevin S. Kim is vice president, northwest region bridge and structures lead, and project manager and Hana D'Acci is bridge design lead with Jacobs in Bellevue, Wash. John Vicente is city engineer for the City of Kenmore, Wash.

Nine vertical "oars" at the overlook on the West Sammamish River Bridge multiuse path delineate its position and importance Photo: Jacobs.

Picture Two Bridges in Your Mind's Eye



Were they the Brooklyn Bridge and the Golden Gate Bridge? Most people can picture those two with just a mention of their names. Plus, each of us has our own mental file of bridges, many quite modest, that are familiar features of our hometowns or local landscapes. We have these mental images because those bridges have meaningfully engaged our thoughts, emotions, intuitions, and/or desires, just as great paintings and sculptures do.

Fred Gottemoeller, the aesthetics commentator for *ASPIRE*, has developed a new website that identifies memorable works of bridge art, many of which have been featured in *ASPIRE*. The site demonstrates how these works affect us and why they are so memorable. The site also shows designers how they can make their own bridges succeed as works of art. Finally, it shows community advocates how they can collaborate with designers to make great works of bridge art for their local roads, highways, and waterways.

The website's goal is to improve the aesthetic quality of the bridges built in the coming years, for the benefit of this generation and beyond.

Gottemoeller is considered America's most distinguished expert on bridge aesthetics. He has contributed to the design of more than 35 bridges and bridge proposals. Among them are crossings of the Colorado, Mississippi, Missouri, Niagara, Ohio, and Potomac Rivers.

Check out the site at www.Bridges.art.

Electrical Resistivity—Its Role in Concrete Durability and Quality Control

by W. Jason Weiss, and O. Burkan Isgor, Oregon State University, and K. Siva Teja Chopperla, Indian Institute of Technology

Concrete bridge components play a vital role in the development of long-lasting, durable bridges. The concrete used in precast and cast-in-place concrete components helps protect the reinforcement from the elements, especially chloride-containing deicing/anti-icing salts and saltwater. Concrete that is the most resistant to the ingress of salt from the environment has low porosity (for example, a low water-cement ratio [*w/c*]) and low pore interconnectivity.[1] The use of supplementary cementitious materials (SCMs) such as fly ash, silica fume, natural pozzolans, or slag generally does not reduce the overall porosity significantly; however, it can refine the pore structure to reduce pore connectivity.[1–3] As a result, the use of SCMs generally increases concrete resistance to fluid and salt ingress.

Questions exist about how to determine the resistance of a material to the ingress of chloride-containing salt and how to specify these materials. The rapid chloride permeability test (RCPT) is commonly used to quantify the resistance of a material to salt (chloride ingress).[4,5] It requires making cylinders, cutting them at the testing age, conditioning them by vacuum saturation, and exposing them to an electrical current for 6 hours. This test is destructive, and, like all testing, it has associated costs and reported errors, which, for this test method, are particularly associated with the use of electric potential.[6–8] The RCPT provides an indication of the electrical conductivity of the tested specimen, rather than its ionic transport properties. Salt-ponding tests can also be used, but these tests are destructive, time consuming, and costly, and they only correspond to one type of salt and salt concentration under ponding conditions.[9,10]

An alternative measure of transport—part of the American Association of State Highway and Transportation Officials' (AASHTO's) publication R 101[11]—measures the electrical resistivity of concrete using bulk resistivity (AASHTO T402-23),[12] surface resistivity (AASHTO T358-22),[13] or embedded electrodes (**Fig. 1**). Measuring electrical resistivity is a nondestructive test, which means it can be repeated over time to gauge property development. While the sample does need time to cure and condition, the resistivity testing itself is relatively rapid and should therefore have lower costs than other methods.

Several recent efforts have been made to quantify the accuracy of resistivity testing. For example, a verification cylinder (**Fig. 2**) was created using resistors and capacitors that were capable of simulating concrete with a high and low performance according to

Figure 1. Test geometries used to measure the electrical resistivity of concrete. Figure: Oregon State University, adapted from Spragg et al. (2013).[10]

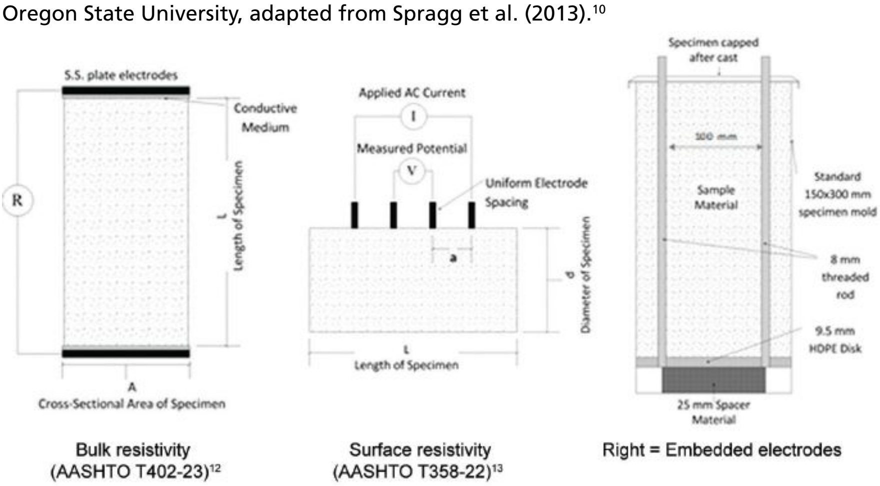


Figure 2. Verification device used to train users and evaluate the bias of commercial testing devices. Photo: Oregon State University.

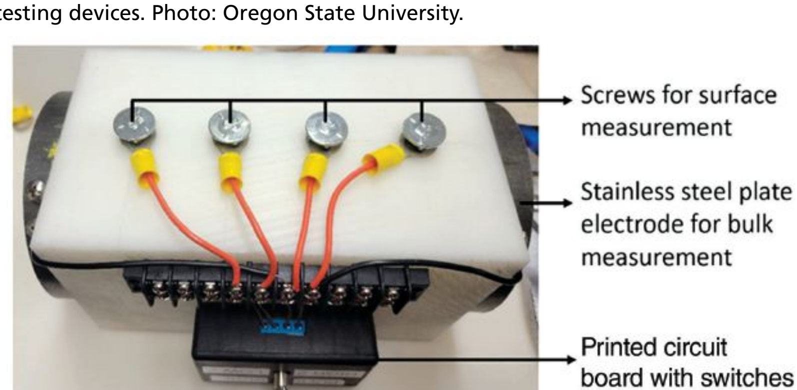


Table 1. Single-operator and multilaboratory coefficients of variation for various conditioning methods

Testing description	Testing standard	Conditioning method		
		Simulated pore solution	Sealed	Lime solution
Single operator	AASHTO T358: Surface resistivity[13]	6.3*	3.8*	5.8
	AASHTO T402: Bulk resistivity[12]	3.3	3.4	2.2*
Multilaboratory	AASHTO T358: Surface resistivity[13]	14.1*	11.0*	10.9
	AASHTO T402: Bulk resistivity[12]	13.0	11.3	9.5*

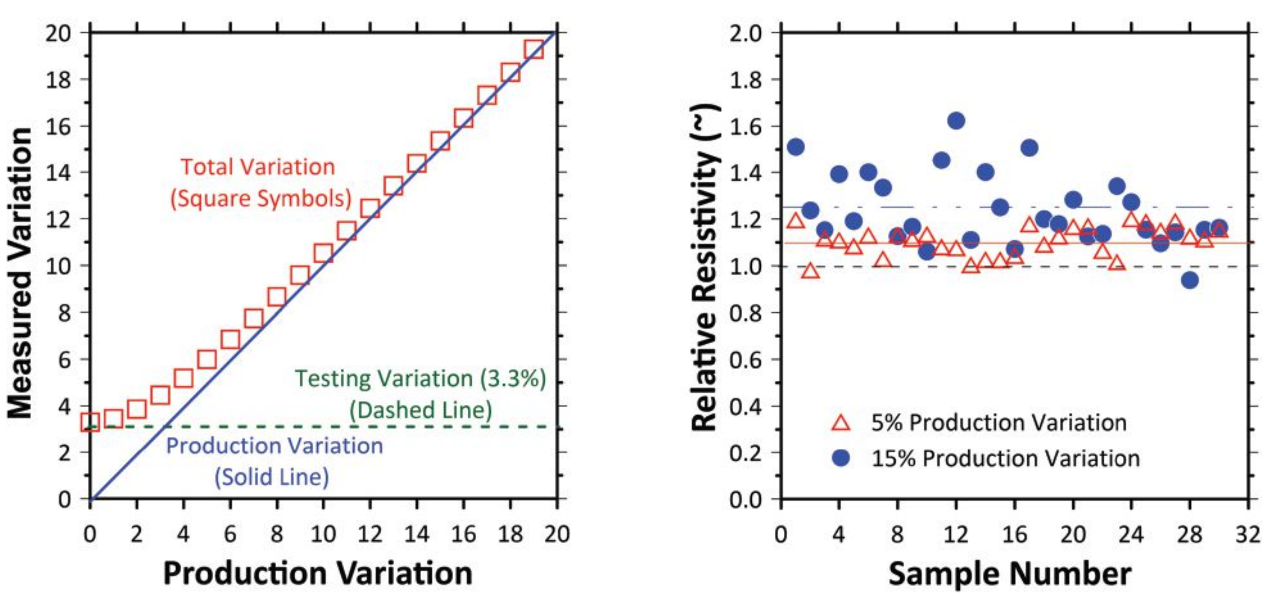
*Conditioning procedure not specified by AASHTO standard.

ASTM C1202[4] (RCPT of approximately 100 to 1000 C and more than 4000 C, respectively).[14] The verification device has two uses. First, it can be used for training new users and evaluating their ability to perform the test correctly. Second, it can be used to evaluate the bias (a measure of how far the measured value is from a true or known value) of various commercial testing devices. The results have a bias of 2.4% or less. **Table 1** provides the measured single-operator and multilaboratory coefficients of variation for the testing.[14] The conditioning method alters the ionic strength of the pore solution in the concrete, and it is important to know the ionic strength as it can be used along with the resistivity to determine the formation factor,[15] a fundamental measure of the pore structure that can be determined with the measured resistivity and information about the pore solution.

Single-operator precision testing is performed to quantify the acceptable variability when two tests are performed by the same operator. These data can be very useful for quality-control operations as they help establish the level of variability that can be expected from the test before the variability of the material processing is considered. Variations equal to or less than the single-operator variation are expected, and no changes in process should be needed. Table 1 shows the single-operator variations for the bulk and surface tests for three sample conditions. The total variation σ_{Total} of a measured sample collected during a construction project is the square root of the sum of the squares of the intrinsic material variability s_M, the sampling variability s_S, the testing variability s_T, and the production variability s_P. The the precision reported by the testing standard accounts for the first three sources of variability, whereas the production variability is related to how precisely the contractor can control the concrete constituent materials, mixing process, and placement. **Figure 3** illustrates the relationship between the measured variation (on the y axis) and the production variation (on the x axis). To achieve the target resistivity for a material with 95% confidence considering no production variation, the material should be designed with a mean that is 1.055 times the target value ($1.65 \times \sigma_{Total}$). Similarly, if a material has a production variation of 5%, 10%, 15%, or 20%, the mean value should be designed such that it is 1.10, 1.16, 1.25, or 1.30 times the target value, respectively.

The multilaboratory testing represents the acceptable variability when two tests are performed by different operators with different equipment (both the testing device and, more importantly, the curing and conditioning methods). This type of testing would be used to compare two different laboratories—for example, the producer performing quality-control and the owner performing quality-assurance testing, assuming these tests are done independently. The variation in testing devices is relatively low (generally, a coefficient of variation of less than 2%);

Figure 3. An illustration of the role of testing, production, and total variation, and how production variation and testing variation can affect the relative resistivity design target. Figure: Oregon State University.



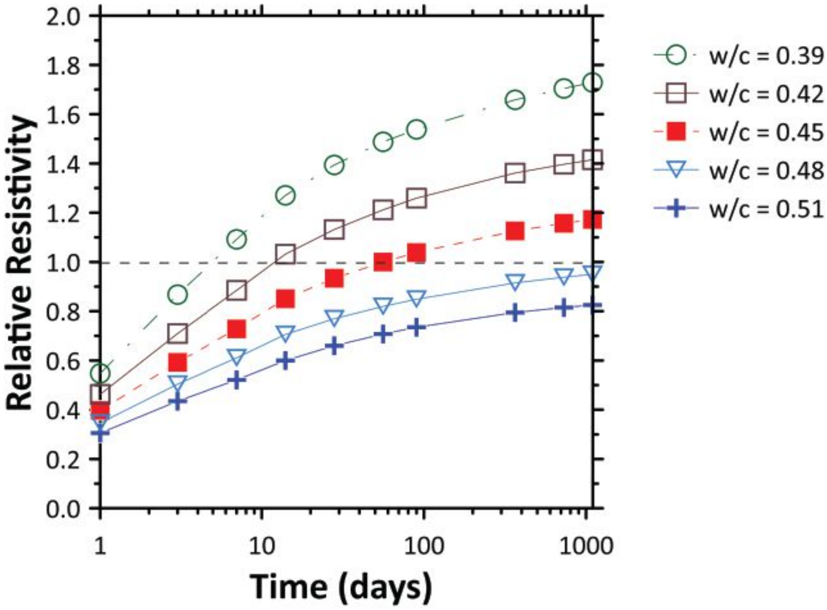


Figure 4. Predicted relative resistivity development for concretes with varying water-cement ratios. Figure: Oregon State University.

Table 1 shows the conditioning of samples and inherent material variation.

One benefit of using resistivity is the ability to track the development as a function of time. **Figure 4** estimates the relative resistivity development over time using thermodynamically based theoretical calculations for concretes with various *w/c*.[16–20] Two things become evident. First, the concretes with lower *w/c* have a higher resistivity. Second, and maybe more subtle, when specific resistivity values are required to meet a specification, they can be monitored over time and "deemed to satisfy" before a specific age. This monitoring also has the potential to be used as an early indication of long-term compliance.

While there are many benefits of resistivity testing, new users of the test should be aware that—unlike more classical tests such as strength—it may be impacted by testing temperature, sample conditioning, steel fibers, certain corrosion inhibitors, and degree of saturation.[10,21–24]

In summary, the electrical resistivity of concrete can be measured easily and provides useful information for quality control and quality assurance in concrete materials. Resistivity is a rapid, relatively low-cost, nondestructive test method to assess resistance to fluid and ion transport. This article outlines aspects of testing variation and indicates how they could be used for quality control. Furthermore, resistivity can be extended to service-life predictions, which can be beneficial in quantifying the long-term performance of concrete materials.[25]

Acknowledgments

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CONCRETE BRIDGE TECHNOLOGY

Engineering for Bridge Demolition

by Josh Crain and Lisa Briggs, Genesis Structures; Michael Haas, Collins Engineers; Samantha Kevern and Chris Tollefson, Foothills Bridge Co.

According to the American Society of Civil Engineers (ASCE) *2021 Report Card for America's Infrastructure*,[1] the average age of bridge structures in the United States was 44 years; 42% of all bridges are more than 50 years old. Updating, repairing, and replacing the bridges in the National Bridge Inventory will require significant bridge demolition operations.

Poorly planned bridge demolition operations have caused property damage, unexpected road closures, injuries, and fatalities. Demolition problems can result in additional costs, project delays, impacts to public traffic, and adverse publicity for the contractor and owner. A properly engineered demolition plan includes the analysis of the bridge structure during the operation stages and provides work sequences that reduce risks and potentially negative outcomes.

Bridge demolition operations can be either complete or partial demolition of existing structures. In complete demolition operations, the entire bridge structure is permanently removed and the demolition sequences can be analyzed—assuming that the remaining service life is finite and known—without considering future use. Partial bridge demolition may involve limited removal of the bridge structure as required for repairs or partial bridge replacement. The remaining structure remains in service and must be protected to ensure that the service life of the rehabilitated bridge is not adversely affected by demolition activities. Although analyses of complete and partial demolition are similar, the design limits and criteria vary. The load factors used for strength-level limit state checks of bridges under complete demolition can be lower than the load factors for bridges under partial demolition. The difference in load factors is comparable to operating-level design limits for complete demolition and inventory-level limits for partial demolition.[2]

Engineering analysis used for bridge demolition operations must be appropriate for the type and configuration of the structure being analyzed. The analysis must take into consideration the condition of the concrete, changes to the structure during each stage of the demolition operation, and the equipment used. Complex bridge demolition analyses require an experienced engineer.

Ultimately, it is up to the contractor and their engineer to determine the most effective demolition method and to develop a plan for the work to be performed safely, within the constraints of the project contract documents.

Equipment Loading for Bridge Demolition

In general, bridge demolition has three phases: deck removal, superstructure removal, and substructure removal. The equipment used for each phase is selected based on the structure type, site conditions, contractor preferences, and project schedule. In many cases, when bridges are being demolished or rehabilitated, construction equipment must be supported by the bridge structure being removed. In these cases, the actual equipment loads and their locations, including moving load effects, should be used to evaluate the structure's adequacy at each stage of partial removal.

While knowing the weight of specific demolition equipment is straightforward, understanding the weight distribution and dynamic effects of the equipment during demolition activities becomes complicated. It is the engineer's responsibility to determine the wheel, track, or outrigger loading based on the machine weight, attachments, operating radius, and dynamic impact from the work being performed. For some types of equipment, such as cranes, bearing-pressure calculation software may be available. For other types of equipment,

Figure 1. The top flange of this concrete girder was damaged during demolition. If the girder is to remain, it must be repaired. Photo: Collins Engineers.

the engineer must determine the loading based on hand calculations or finite element modeling of the equipment. The level of conservatism or need to accurately determine the applied equipment loading will vary depending on the project and structure's capacity.

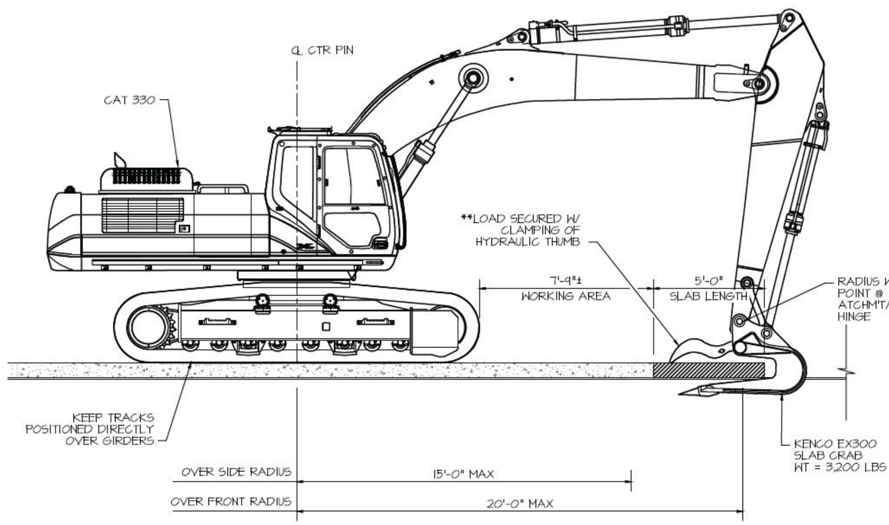

Figure 2. Schematic of an excavator removing precut deck panels using the "slabbing" technique, which minimizes falling debris. Figure: Steamboat Structures.

Deck Removal

Deck removal is typically performed with an excavator equipped with an attachment specific to the selected removal method. Two common removal methods are (a) cutting and removing the deck in panels and (b) breaking and dropping the deck out with a hammer. When choosing a method for deck removal, contractors must consider what the bridge is spanning and whether the girders are to be reused. If the existing girders are to be reused, the demolition contractor must take additional care during deck demolition to minimize damage to them. If the top flange of the girder is damaged, typical concrete patch repairs on spalls or epoxy injection in saw cuts may be adequate to restore the structural integrity of the girder (**Fig. 1**). However, the location, severity, and depth of the damage must be analyzed in correlation with possible prestressing or post-tensioning strand or bar locations to ensure that the primary load-carrying reinforcement was not compromised. In such cases, analysis may indicate that strengthening or replacing the damaged girder is required.

When demolition activities take place over live traffic, a railroad, environmentally sensitive areas, or a waterway, controlled removal methods are typically preferred. The most common removal method is to precut panels and remove them using a slab crab or grapple attachment (slabbing). Slabbing helps minimize the amount of falling debris and reduces the effects of the dynamic impact that the equipment induces on the structure (**Fig. 2**). Once the deck panels are removed with the excavator, they are then transported off the bridge using support equipment, such as flatbed trucks, front-end loaders, or skid steers; then the panel pieces can be processed using a pulverizer/muncher or other specialty excavator attachment.

Demolition contractors generally prefer to saw cut a grid of manageable-sized deck pieces in advance to speed up the removal process. Most concrete girder bridges were designed to act compositely with the reinforced deck, and saw cutting longitudinally along the girder edges disengages a significant portion of the composite deck. The capacity of the superstructure with a saw-cut deck must be analyzed for the weight of the deck in combination with equipment removing the cut pieces.

The most efficient deck removal method is using a hammer or shear attachment to break the deck to the ground or shielding below. When demolitions occur over a finite outage period, these methods are often used for partial deck removal to separate the girders (**Fig. 3**). The deck over the girder flanges remains and can either be hoisted out with the girders or removed later using smaller handheld tools if the girders are to be reused.

Superstructure and Substructure Removal

Superstructure and substructure removal are performed by either saw cutting to lift components out with a crane or pulling portions of the structure over with an excavator from the ground. When dealing with a concrete superstructure, components are generally very heavy, and it is critical to correctly size equipment to handle these large loads. It is also important to remember that in demolition, a component that is being removed often cannot be set back down, so accurate estimates of component weight and center of gravity are crucial to safe removal operations. If detailed plans are not available to adequately determine component weights, field measurements or additional factors of safety, or both, are recommended.

Figure 3. Excavator with a shear attachment breaks the deck to separate the girders. Shear attachments are hydraulically controlled jaws used to cut reinforcement, concrete, and structural steel members. The thickness of steel that shears can cut is dependent on the specific shear attachment and size of excavator. Photo: D. H. Griffin.

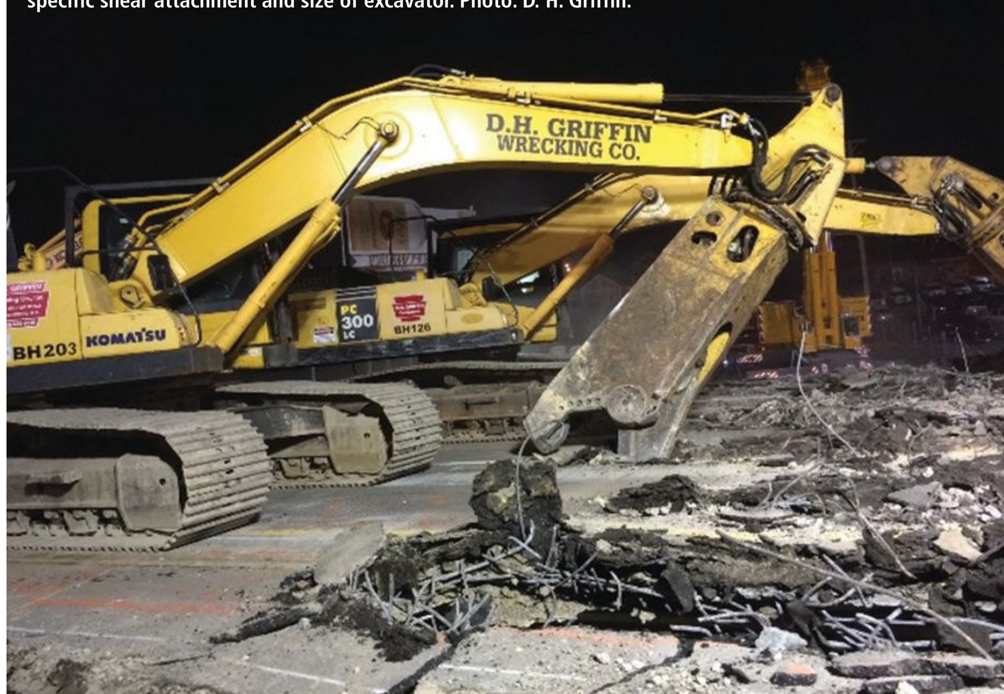

Figure 4. During demolition of a bridge superstructure, a prestressed concrete girder is removed using a single-crane pick. The demolition engineer should verify the proposed lifting configuration to ensure stability of the girder during its removal. Photo: Collins Engineers.

With the deck removed and the excavators no longer loading the structure, additional engineering effort is required to ensure the safe and stable removal of the superstructure. During initial construction, prestressed concrete girders generally need to be lifted at or near the ends of the girder to ensure that the tensile stresses in the top flange are within limits. Demolition contractors often prefer to use a single crane for girder removal to avoid the additional cost and site logistics of positioning a second crane. The demolition engineer should verify the proposed lifting configuration to ensure girder stability and to avoid failure of the girder due to the combined negative moments from the prestressing strands and the self-weight of the cantilevers beyond the proposed lifting points (**Fig. 4**).

Demolition of post-tensioned (PT) structures can result in unexpected behavior if the PT strand or bar configuration, grouted or ungrouted conduit condition, and sequencing of PT disengagement during demolition are not thoroughly analyzed. Ungrouted PT strands can be as dangerous as a flying projectile when severed and the tensile stress is released. Detensioning PT strands and losing the continuity over multiple spans can result in significant capacity reductions; various PT structure types may not have the capacity to support the self-weight of the concrete superstructure without the continuity of the PT engaged.

Deck removals or replacements on PT structures must also be carefully planned. The engineer cannot simply assume that the deck can be removed without an understanding of the composite behavior of the PT strands in combination with the superstructure and the deck. Partial or full removal of the deck could affect the composite properties of the primary post-tensioned sections, compromise the integrity of the PT strands, or inadvertently cut or damage PT strands relied upon to support the dead load of the structure. An understanding of the type of post-tensioning and the design intent is essential to appropriately analyze the demolition sequence. Conservative methods of shoring for the structure self-weight should be considered.

Conclusion

Evaluation of the capacity of existing structures should take into account the current condition of the structure, and the limit states for evaluation should be based on something similar to "operating-level" evaluations as presented by the American Association of State Highway and Transportation Officials' *Manual for Bridge Evaluation*.[2] Ultimately, however, capacity determination is at the discretion of a qualified structural engineer.

Proper consideration of the demolition sequence is as important as the evaluation of bridge structures during the various stages of construction. Structural engineers evaluating demolition sequences must be aware of the loads, the load paths, and the structure's changing stiffness and response as a bridge is being dismantled. Failure to account for all of these factors can lead to unexpected results in the field.

Owners and stakeholders can further enhance project safety and mitigate project risk by adopting bridge demolition guidance, requirements, and oversight. The Bridge Demolition Subcommittee of the American Society of Civil Engineers (ASCE) Construction Institute Temporary Works Committee is currently working on the first edition of a bridge demolition best-practice document to be published by ASCE in the spring of 2024.

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Modified Prestressed Concrete Slabs with a UHPC Connection for West Fork Dairy Creek Bridge

by Clayton Davey and Dr. Tanarat Potisuk, Oregon Department of Transportation

Precast, prestressed concrete slabs are a common concrete superstructure type for short- to medium-span bridges in Oregon. Traditionally, side-by-side precast, prestressed concrete slabs are connected with transverse tie rods, topped with waterproofing membrane, and paved with an asphalt concrete wearing surface to complete the bridge deck system. Bridges with these connection details have historically required frequent wearing-surface maintenance due to differential deflection between slabs activated by broken tie rods and eventual keyway failure (**Fig. 1**).

To mitigate this issue, the Oregon Department of Transportation (ODOT) revised the slab connection details to use a series of tie rods installed sequentially between each adjacent slab, instead of one tie rod for a full bridge width, and to add nut-tightening requirements. The new tie-rod system has performed better; however, the construction requires additional steps and time. A reinforced concrete deck has also been used to create a composite section that eliminates the need for tie rods. This method results in a deeper superstructure. Given tight site constraints, the deeper slab section can result in inadequate hydraulic freeboard or lead to costly roadway approach work.

Ultra-high-performance concrete (UHPC) is an excellent material for joint connection and is promoted through the Federal Highway Administration's Every Day Counts initiative. ODOT's first project using UHPC was in 2011, when UHPC was used for the connections between full-depth precast concrete deck panels and between precast concrete deck panels and bulb-tee girders. In 2017, ODOT expanded use of UHPC for connecting adjacent deck bulb-tee girders. Since then, ODOT has published standard details for use by bridge designers and added design guidelines in the ODOT *Bridge Design Manual*[1] for this girder system. The system reduces construction steps and time, allowing a bridge to be built faster.

The West Fork Dairy Creek Bridge project team seized the opportunity to try new details for connecting side-by-side prestressed concrete voided slabs using UHPC, the first such application in Oregon. This method eliminates the need for transverse tie rods without the additional depth of a cast-in-place deck. The bridge deck system includes a minimum ¾-in.-thick polymer concrete overlay.

The bridge carries a section of Oregon Route 47, a two-lane highway with one lane in each direction, just north of the city of Banks, Ore. It has been projected that the average daily traffic for this stretch of the highway in 2040 will be 5600 vehicles, with trucks accounting for 28% of these vehicles.

This project replaced the 85-year-old timber bridge that had deteriorated beyond repair. The new single-span bridge is 44 ft wide and 63 ft long, supported by 16-in.-diameter steel pipe piles at the abutments. The bridge design employed the new UHPC connection system using eleven 27-in.-deep and 4-ft-wide precast, prestressed concrete voided slabs.

Figure 1. Examples of side-by-side precast, prestressed concrete slab bridges with keyway failures. On the left is a broken, full-width tie rod hanging from the side of a prestressed concrete slab. The photo on the right shows reflective cracks at the joints between prestressed concrete slabs. All Photos and Figures: Oregon Department of Transportation.

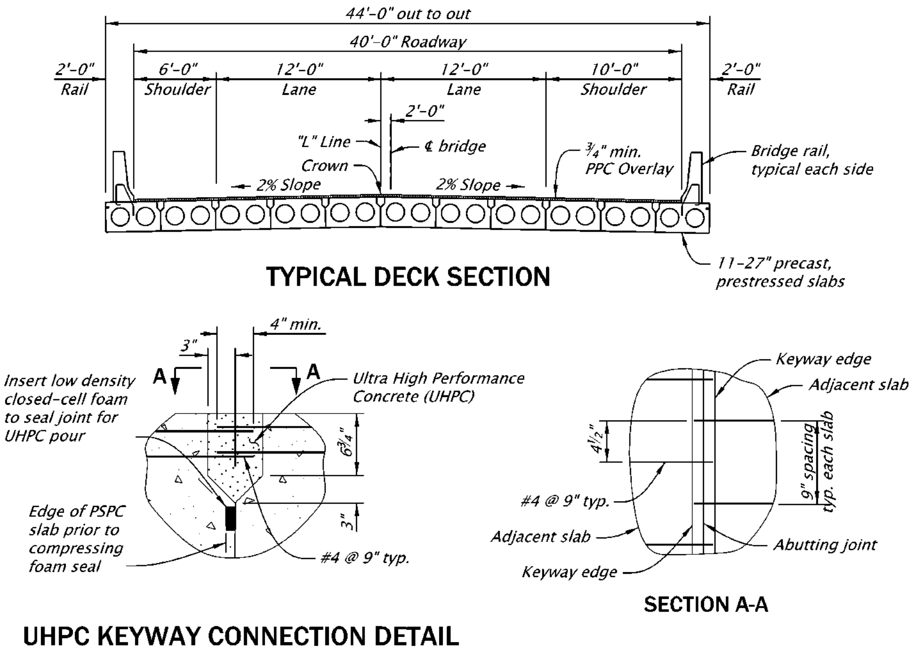

Figure 2. Cross section and details for the West Fork Dairy Creek Bridge with precast, prestressed concrete voided slabs connected with a larger shear key, noncontact lap splices of transverse dowels, and an ultra-high-performance concrete closure pour.

During the design development phase, input from the local precast concrete producer was considered for the development of the slab details. The modified prestressed concrete voided slabs included an enlarged keyway to accommodate the noncontact lap splice of the steel reinforcement extending from the precast concrete components. The keyway depth was set to have similar performance as a conventional 8-in.-thick reinforced concrete deck—the minimum required by the ODOT *Bridge Design Manual* for a spread-girder system. A clear cover of 3 in. for the top surface was specified to allow for grinding overfilled UHPC keyways and surface preparation for the polymer concrete overlay. This design will achieve the required 2.5-in.-thick minimum clear cover for the top surface of the bridge deck. **Figure 2** shows the cross section and details of the new West Fork Dairy Creek Bridge, and **Fig. 3** shows the prestressed concrete voided slabs in place before placement of the UHPC in the longitudinal joints. With only a thin (¾-in.-thick) overlay specified, the project special provision required that the contractor adjust the camber of adjacent slabs such that adjacent slabs would have a differential camber of ¼ in. or less at midspan before the UHPC for the connections was placed.

The ODOT BDM requires adjacent girders that function as the roadway surface and are connected with UHPC to have at least 15% more capacity than the capacity needed when the roadway is in service, to make up for potential additional loads from the camber-adjustment process. The design must also account for the ½-in. sacrificial thickness of the clear cover.

The unit cost of the precast, prestressed concrete voided slabs was higher than usual because the slab forms required modification. The reinforcing bars for the joint connection extended into the joint space for noncontact lap splices (**Fig. 4**). The option of form-saver bar couplers was made available but was not used. A commercial UHPC product was specified for the connections. The contractor wanted to use traditional concrete mixers instead of the high-shear mixers normally used for mixing UHPC. As a precaution, several concrete mixers were provided on site to provide continuous mixing. The traditional mixers took longer to blend the material, and one of the motors burned out during the mixing of the first batch.

At one point during the UHPC placement, the ambient temperature at the bridge site dropped below 30°F. The UHPC manufacturer requires cold-temperature mitigation measures when the ambient temperature on the concrete surfaces falls below 40°F during the mixing. Unfortunately, the special provision did not include specific requirements for such

Figure 3. Precast, prestressed concrete slabs for the West Fork Dairy Creek Bridge after erection. The joints were soaked with water to create a saturated surface-dry condition, and concrete ecology blocks were used for adjusting differential camber.

Figure 4. The contract specifications required an exposed-aggregate surface finish in the keyway pocket of the closure pour. The bottom of the keyway pocket is sealed to prevent the fluid ultra-high-performance concrete from seeping.

Figure 5. Heating with containment is used for cold-temperature mitigation during the ultra-high-performance concrete closure pours.

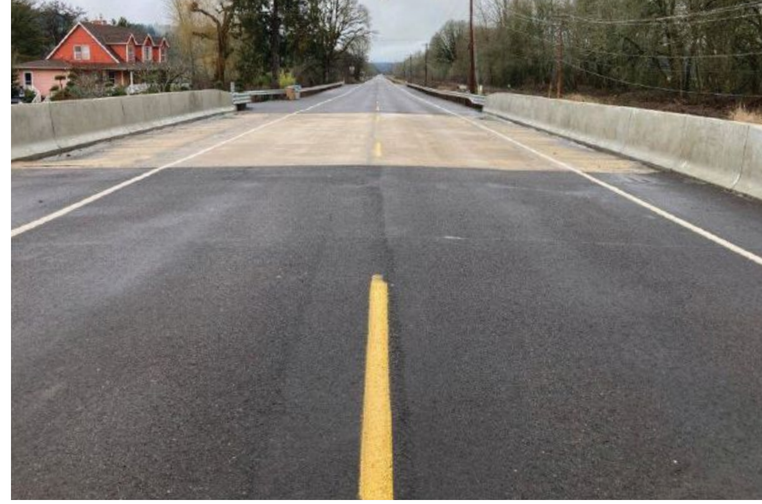

Figure 6. The West Fork Dairy Creek Bridge after installation of a ¾-in.-thick polymer concrete overlay.

unanticipated cold temperatures during the UHPC placement. In accordance with the manufacturer's recommendations, thermocouple sensors were placed within the UHPC material to monitor and record the curing temperatures. Forced-air heating with containment was provided under the deck in tandem with insulated curing blankets on top to raise the surface temperature to above 40°F. **Figure 5** shows the cold-temperature mitigation measures.

Figure 6 shows the new West Fork Dairy Creek Bridge. Its successful completion in November 2022 encourages the use of these new connection details for precast, prestressed concrete slabs on other future bridge replacements. With minor refinements to the specifications and details, these modified prestressed concrete slabs with UHPC connections can enable quick construction and provide another alternative for the precast, prestressed concrete slab system.

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The American Segmental Bridge Institute: 35 Years of Continuous Improvement

by Gregg Freeby, American Segmental Bridge Institute

The first post-tensioned concrete segmental box-girder bridge built in the United States was the JFK Causeway on Park Road 22 in Corpus Christi, Tex. It was opened to traffic in 1973. (For details of the bridge's original construction and its condition, see the Project article in the Summer 2021 issue of *ASPIRE®*.) This first project began a slow but steady growth in the use of the concrete segmental construction method in the United States. After a few years, there was an increasing need for a professional organization that could facilitate the further advancement of this innovation.

After a meeting of key individuals, including Eugene Figg of Figg & Muller Engineers, John Kulicki of Modjeski and Masters, and J. D. Pitcock Jr. of Williams Brothers Construction, a new institute was formed and incorporated in 1988, the American Segmental Bridge Institute (ASBI).

Cliff Freyermuth served as ASBI's executive director from its inception until his retirement in 2008. He and the ASBI board of directors were instrumental in establishing the group as a key organization in the development of the segmental method through seminars, training, and an annual convention. ASBI's first annual convention was held in 1989 in San Diego, Calif., and drew just under 170 attendees. Since that time, the ASBI annual convention has seen steady growth in attendance. ASBI hosted their 35th annual convention in Tucson, Ariz., in October 2023, with more than 300 attendees. In 2009, ASBI gained a new executive director, William "Randy" Cox, the former Texas state bridge engineer. Cox led ASBI through continued growth and challenges until his retirement in 2018. Beginning in 2019, the author has had the honor of leading ASBI after a 30-year career at the Texas Department of Transportation.

A presentation at the 2023 American Segmental Bridge Institute (ASBI) annual convention. Part of ASBI's scope is to work collaboratively to advance, promote, and innovate concrete segmental bridges and complex concrete structure technologies. This includes sharing knowledge, educating stakeholders, and providing sustainable and resilient solutions. Photo: American Segmental Bridge Institute.

According to the incorporation filing, ASBI was founded for the following reasons: "To advance the use of segmental and cable-stayed bridges. To provide a forum where designers, contractors and owners can meet to develop the techniques and procedures that will continually advance the art, engineering, and quality of concrete segmental and cable-stayed bridge construction." ASBI's early focus was on reducing contractor claims associated with unclear or ambiguous contract requirements and uncertainty as to how bridges were built using this method. This emphasis on "designers, contractors and owners" was unique at the time. In fact, even today, few organizations focus on these three stakeholders in the execution of bridge projects. It is this three-pronged approach that has proven to be ASBI's biggest strength over the years. This approach enables ASBI to assemble the right individuals to problem-solve and collaborate.

It is significant to note that ASBI was formed as an institute and not as an association. Typically, an association is created to represent the interests and promote the common goals of its member companies. In contrast, an institute is usually focused on education, research, training, and professional development within a specific industry or field. While it may also represent the interests of its members, the primary emphasis of an institute is on advancing knowledge, skills, and expertise in the industry.

To that end, ASBI's original incorporation filing also states the following as one of the purposes for the organization: "The dissemination of information and knowledge about all aspects of segmental

The navigation unit of the Marc Basnight Bridge, Outer Banks, N.C., is a 3550-ft-long, 11-span, continuous post-tensioned concrete segmental structure. It received the 2019 American Segmental Bridge Institute Award of Excellence. Photo: HDR.

and cable-stayed bridges through seminars, workshops, conventions, printed public, electronic, photographic and other educational media."

Over the years, ASBI has seen many challenges and opportunities. In 2000, issues related to the grouting of post-tensioned structures began to become an area of concern to bridge owners. ASBI quickly mobilized a group of experts to develop training and specifications for the grouting of post-tensioned structures. The first ASBI Grouting Certification Training class was held August 6 to 8, 2001, at the J. J. Pickle Research Center at the University of Texas–Austin. One hundred forty engineers and construction personnel participated in the class. Since then, ASBI has trained over 2800 installers, supervisors, and inspectors in the proper specifications and procedures for grouting post-tensioned structures.

To provide additional guidance for the construction of concrete segmental bridges, ASBI publishes the *Construction Practices Handbook for Concrete Segmental and Cable-Supported Bridges*.[1] The current third edition was published in 2019. This handbook provides a basic understanding of concrete segmental construction technology. The overall goals are to facilitate the construction process, avoid common difficulties previously encountered, and reduce impacts to projects.

Concrete structures have grown in complexity in recent years, and so the ASBI board of directors voted at their 2023 annual meeting to expand the institute's scope to include complex concrete structures. The new mission statement reads: "To work collaboratively to advance, promote, and innovate concrete segmental bridges and complex concrete structure technologies; share the knowledge; educate stakeholders; build professional relationships; and increase the value of our infrastructure by providing sustainable and resilient solutions." ASBI is still refining what will be included under the "complex structures" definition, but it is envisioned to include structures such as precast concrete arches, continuous spliced girders, precast, post-tensioned concrete substructures, and concrete structures that require a specialty engineer during construction.

To monitor the performance of concrete segmental bridges, ASBI regularly produces the *Durability Survey of Segmental Concrete Bridges.*[2] This report uses the bridge inspection data found in the National Bridge Inventory database to evaluate the long-term performance of concrete segmental bridges. (See the Winter 2023 issue of *ASPIRE* for more information about this report.)

From the latest durability survey, it is clear that concrete segmental bridges continue to show excellent durability performance. Of the major bridge types in the inventory, concrete segmental bridges have the lowest percentage of poor-rated bridges, with only 0.7% rated in the poor category (details are provided in the survey). In the 50 years since the first concrete segmental bridge in Texas, the performance of the concrete segmental bridge inventory has been outstanding and further demonstrates the benefits of concrete segmental construction.

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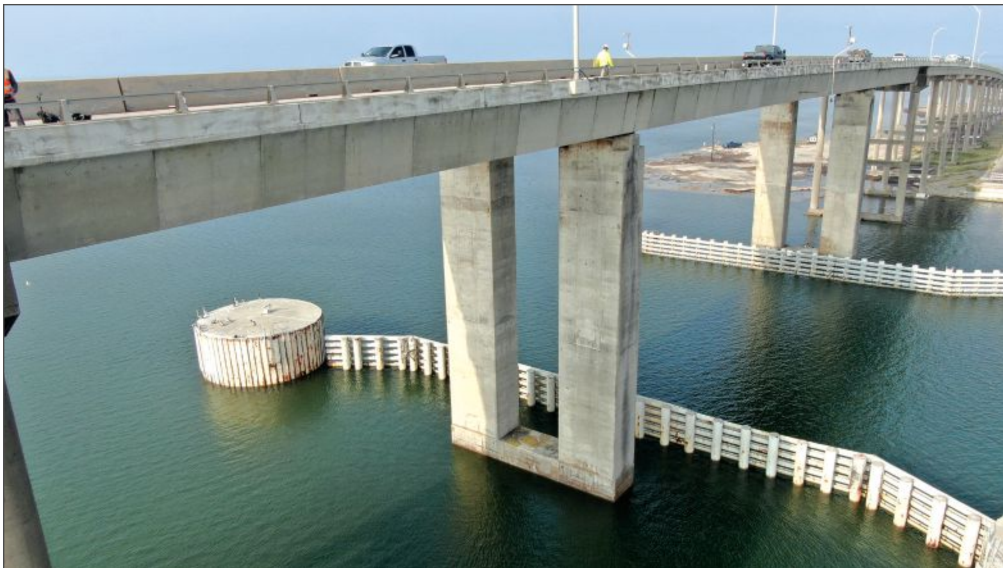
Gregg A. Freeby is the executive director of the American Segmental Bridge Institute and chair of the National Concrete Bridge Council.

JFK Causeway Bridge in Corpus Christi, Tex., which opened in 1973, was the first post-tensioned concrete segmental box-girder bridge built in the United States. Photo: Wiss, Janney, Elstner Associates.



Bridging Traditions: Merging Cast-in-Place Concrete with Modular Construction

by Aubri Benson, InQuik Inc.

Designers and constructors seek both efficiency and durability in today's concrete bridges. While some projects are suitable for cast-in-place construction methods, constrained sites often require prefabricated solutions.

In Eau Claire County, Wis., an innovative project merged cast-in-place and modular construction by using a new method for enhanced efficiency. In August 2023, the county used the InQuik Bridge System to replace a functionally obsolete plate arch culvert on County Road V. Because the system is composed of preassembled, pre-engineered components that combine reinforcing steel and stay-in-place formwork, it allows a conventionally reinforced concrete structure to be installed with limited labor resources and equipment.

The InQuik system is modular, and therefore any project that uses the system must use a combination of various "standard" modules. Generally, the deck panels are 8 ft wide. However, 18-in.-wide "extension spacers" can be added between deck panels if needed. Currently, the system is available for spans of 21, 30, 40, 45, 53, and 61 ft with nominal depths of 14.5, 27.5, and 40 in. These standard spans and associated sections have been designed in accordance with the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] for HL-93 loading. Research and development for longer spans and other optimized designs are ongoing.

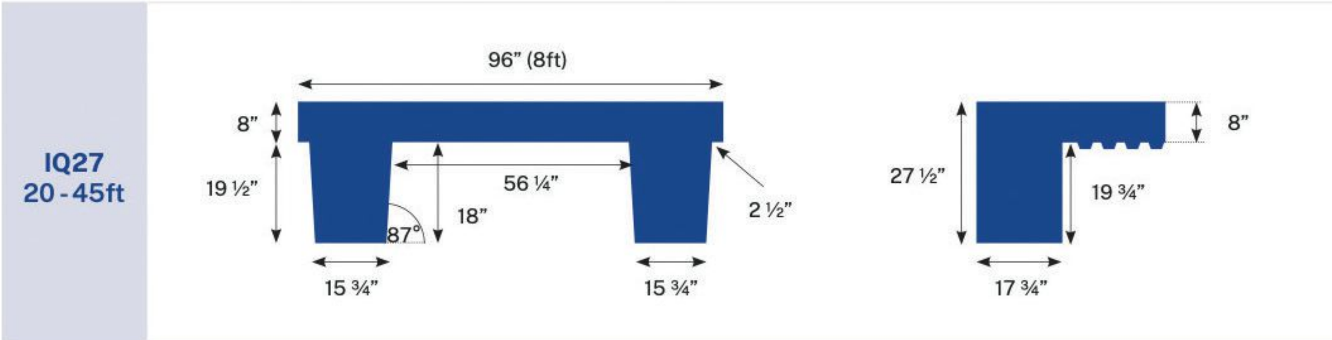
The Eau Claire County project used a standard InQuik section with a span of 30 ft and a section depth of 27.5 in. The bridge cross section used three standard 8-ft-wide modules with two 18-in.-wide spacers for a total width of 27 ft. The bridge incorporated 4-ft-high abutments with an integral connection to the deck units. The abutments featured 45-degree wingwalls that cantilevered off the abutments and required no independent foundations.

A thorough quality-control and quality-assurance program is implemented and documented at the factory to ensure that reinforcement within a module is properly placed. Before concrete placement on the jobsite, the reinforcement can be checked by an on-site inspector for consistency with the design documents. Once the concrete is placed, nondestructive testing for voids can be performed using a sounding hammer. If a defect is detected, the formwork can be removed for remediation.

For the Eau Claire County project, upon the system's arrival on site, a county road maintenance crew lifted the components into place with an excavator and completed some minimal on-site reinforcing work. With pick weights around 5 tons, the county was able to use their own excavator and operator instead of a crane. The prefabricated abutments, with preplaced reinforcing steel inside prefabricated formwork just like the decks, were ready for concrete within an hour of their arrival on site, eliminating the need for a cofferdam or dewatering, which may have been required with conventional construction. The county sourced ready-mixed concrete from a local supplier and placed the concrete themselves.

Because the system is designed to be self-supporting, the need for additional formwork supports or bracing is eliminated. This aspect of the

Eau Claire County Highway Department crews set the final module of the InQuik accelerated bridge construction system for a bridge replacement on County Road V. Photo: InQuik Inc.



The InQuik system is available for spans of 21, 30, 40, 45, 53, and 61 ft with nominal depths of 14.5, 27.5, and 40 in. Figure: InQuik Inc.

system simplifies on-site work, eliminating the need to work below the span and keeping employees and equipment out of the waterway.

For the installation of the structure in Eau Claire County, the schedule was as follows: one day to set abutment modules, one day to place concrete for the abutments, one day to place deck modules, one day to install lap bar and integration bar (to complete the integral connection between the deck and abutment), and one day to place deck concrete. Owing to weather conditions, utility conflicts, subcontractor schedule conflicts, and so forth, the total road closure time was approximately six weeks. However, the InQuik-specific construction processes were completed using about a week's worth of on-site labor with a small (usually four-person) crew.

Use of prefabricated components for this project accelerated the construction such that the duration was measured in weeks rather than the months often required with a conventionally constructed reinforced concrete bridge.

According to Jon Johnson, Eau Claire County's highway commissioner, this methodology reduced bridge construction costs significantly. as compared to the engineer's estimate.

Travis Pickering, the Eau Claire County engineer, says that once he learned about InQuik, he "saw how innovative it was, and that it could be a real game changer. You can install faster and save some money, especially [considering] budgets that keep getting tighter, and rising costs."

Additionally, Pickering notes that the system "goes in faster, [which is] something that's going to have a positive impact on the community as well."

Eau Claire County is planning a second InQuik bridge for construction in 2024. Further east, Marathon County, Wis., is planning to use this system to replace a deteriorated structure in their system.

Reference

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Aubri Benson is a marketing associate for InQuik Inc. in Denver, Colo.

Wind Load on Bridges during Construction

by Brian Witte and Justin Ramer, Parsons

The effects of wind on a bridge vary throughout the life of the structure. There is variability in wind speed and direction; additionally, the size and shape of the structure continually change during construction. These variables drastically affect wind loading. As a bridge is constructed, girders are added, exposed wind area increases, and drag coefficients change until the deck is placed. It is important to consider these changing conditions during the design phase to reduce potential issues during construction.

Brief History Lesson

The American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] provides guidance for wind loads applied on the completed bridge structure, but it does not consider wind load applied during construction. Although the return period is much shorter during construction, the wind-load effects on the partially completed structure are significantly different than those on the completed bridge and may control portions of the bridge design.

Before 2017, there was no specific guidance for wind loads on bridges during construction, so erection engineers relied on their best judgment for erection analysis. The first edition of the AASHTO *Guide Specifications for Wind Loads on Bridges during Construction*[2] was published in 2017 to address wind loads during the construction phase until the deck is placed. The guide specifications provide comprehensive guidance during bridge construction and introduce three new concepts for the temporary condition: revised drag coefficients, drag modification factors based on girder position, and active versus inactive work zones.

The AASHTO Guide Specifications for Wind Loads on Bridges during Construction *introduced*

- revised base drag coefficients for bare girders versus the completed bridge,
- drag modification factors on undecked, multiple-girder systems, and
- definitions of active and inactive work zones.

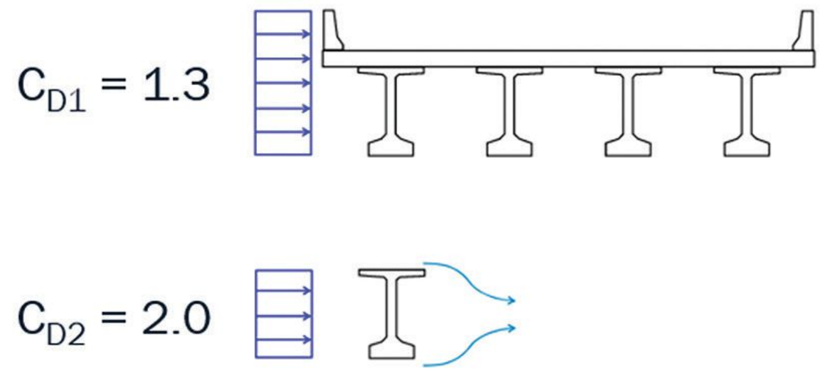


Figure 1. Due to airflow around the bare girder, the base drag coefficient C_D on a bare precast concrete girder is greater than on a completed bridge, even though the completed bridge has a larger area exposed to wind. Figure: Parsons.

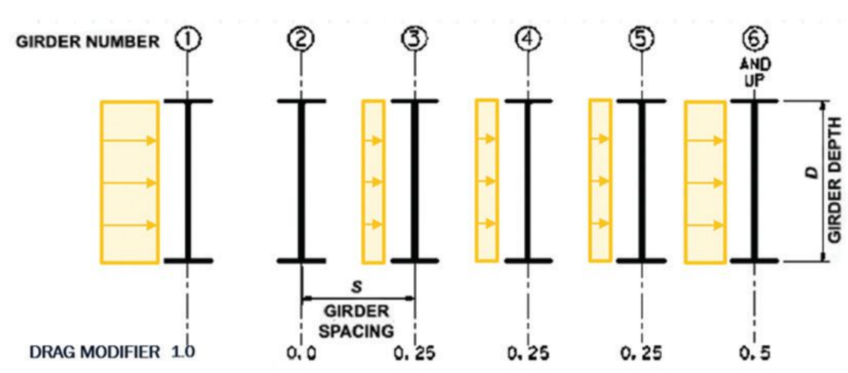
Base Drag Coefficients for Bare Girders

For bridge design, the AASHTO LRFD specifications provide a drag coefficient of 1.3 for the completed bridge to be applied to the exposed area from the bottom of the lowest girder to the top of the barrier. However, the AASHTO guide specifications for wind loads during construction specify drag coefficients that are significantly higher for girders before the deck is placed (for example, 2.0 for a bare precast concrete I-girder and 2.2 for a bare steel I-girder). The increased base drag coefficient is a result of the air's ability to flow around the bare girder, which is prevented once the deck is placed (**Fig. 1**).

Drag Modifier on Undecked, Multiple-Girder Systems

In multiple-girder systems, a modifier is applied to the base drag coefficient

Figure 2. Drag modifiers for leeward girders with spacing-to-depth ratios less than 3, which are common for most bridges. Figure: Modified from Fig. C4.2.1-1 in the American Association of State Highway and Transportation Officials' Guide Specifications for Wind Loads on Bridges during Construction.[2]



C_D depending on the girder spacing-to-depth ratio and the position of the girder in the system (**Fig. 2**). The combined drag coefficient on the system is the product of the base drag coefficient multiplied by the sum of the individual girder drag modifiers (C_D × sum of drag modifiers). The combined drag coefficient is 2.0 with one or two girders erected but increases to 4.5 with six girders erected. **Table 1** shows that the combined drag on the system continues to increase as more girders are added. Typically, the worst-case loading for an individual girder exists with only one girder erected but the highest total wind load on the system occurs when all girders in the cross section are erected.

Active versus Inactive Work Zones

The AASHTO guide specifications for wind loads provide explicit definitions of *active* and *inactive* work zones with distinctly different wind speeds. The work zone is active when workers are on site with erection in progress and subjected to 20-mph winds. The work zone is inactive at all other times, including "time between work shifts," and is subjected to 75-mph winds (the AASHTO guide specifications' 115-mph reference wind speed reduced by a duration factor) for most typical bridges in the United States.

Examples

Figure 3 illustrates how wind loads vary as construction progresses for a typical bridge with eight precast concrete girders. The top portion of the figure shows the wind load after all girders are erected but before the deck formwork. The bottom portion of the figure shows the wind load after the deck and barrier are cast. **Table 2** presents a comparison of the design values for this example bridge. Although the overall structure depth is greater and the wind speed is higher for the completed bridge, the accumulation of drag modifiers on the undecked leeward girders imposes significantly more wind load on the undecked girder-only system.

This example shows that the wind load can be significantly higher during construction than for the remaining duration of the structure's life. In addition, there is a greater risk for girder instability during the construction stage without the deck to brace the compression flange.

Table 1. Examples of system drag coefficients

Number of girders erected	Base drag coefficient	Sum of drag modifiers	Combined drag coefficient on the system
1	2.0	1.0	2.0
2	2.0	1.0	2.0
4	2.0	1.5	3.0
6	2.0	2.25	4.5
8	2.0	3.25	6.5
10	2.0	4.25	8.5

Recommendations

Wind loads during bridge construction should be considered during design. Although the contractor makes final decisions on the girder erection sequence, bridge designers should check critical stages of erection using realistic assumptions to ensure that girders have adequate strength during the intermediate construction phases. If a girder requires strengthening, such as increased flange width or the introduction of top-flange prestressing strands, the designer is the best-suited professional to incorporate these elements into the design. Because such changes may influence the behavior of the in-service structure, these types of decisions should not be left to the contractor or the erection engineer. After the girders have been cast, there are limited options to minimize the impacts of wind loads.

Typical cross bracing between girders helps distribute the wind load among all girders but does not improve the lateral capacity of individual girders (**Fig. 4**). Cross bracing should not be confused with plan bracing (**Fig. 5**). Although plan bracing increases the lateral strength of the bare-girder system, it is rarely used for precast concrete girder bridges.

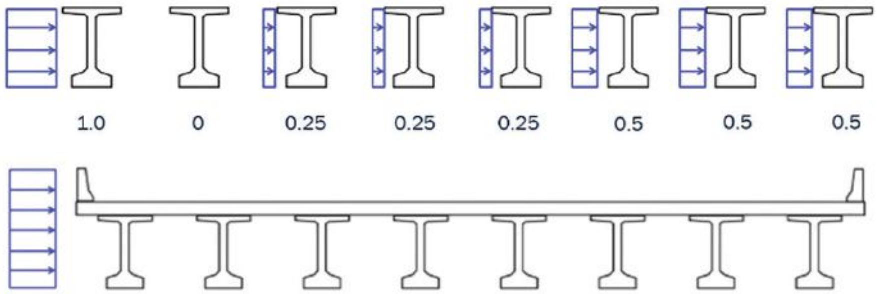


Figure 3. Comparison of wind loads on a girder-only system versus the completed bridge. Figure: Parsons.

Table 2. Comparison of wind load for an example bridge during construction and in the completed condition

	Undecked girder-only system	Completed bridge
Wind speed, mph	115 (inactive work zone)	115 (design)
Duration factor (undecked for 1–6 weeks)	0.65	1.0
Wind speed × duration factor, mph	75	115
Base drag coefficient	2.0 (on fascia girder)	1.3
Base wind pressure, lb/ft^2	28.6	44.0
Sum of drag modifiers of erected girders (see Fig. 3)	3.25	Not applicable
Total lateral wind pressure, lb/ft^2	28.6 × 3.25 ≐ 93.0	44.0
Structure depth, ft	8.5	13
Total wind load on structure, lb/ft	790	572

Figure 4. Typical wood cross bracing helps distribute wind load to all girders but does not provide additional strength to individual girders. Photo: Kicking Horse Canyon Constructors.

Conclusion

Deck formwork significantly reduces the wind load by disrupting the airflow around the girders (which lowers the base drag coefficient) and also eliminates drag on all leeward girders. Even if a diligent contractor installs deck formwork immediately following girder erection, the AASHTO guide specifications for wind loads still require the inactive wind load to be considered during the time between shifts until deck formwork is complete.

Wind loads on an undecked girder system are significant. Instead of spending the time, effort, and expense to resist high wind loads during construction of every bridge, it may be prudent to implement a risk-based system that evaluates how damaged girders would affect the surrounding area. For example, failure of girders erected over a frequently traveled highway would cause much more damage and disruption than a comparable failure at a rural, offline bridge crossing a stream. The current guidance in the AASHTO guide specifications for wind loads does not make a distinction between these types of bridges during construction.

The addition of another work zone category between active and inactive is worth considering. The most critical wind-exposure time frame occurs between girder erection and deck forming, but this time could be as little as one week for precast concrete bridges. It is easy to reasonably predict the threat of severe weather within a relatively short time frame following erection (for example, 7 to 10 days). Project teams use forecasts to determine if weather conditions are suitable to cast and cure concrete, but this concept is not used for wind loads. Allowing owners and contractors to use weather forecasts to place reasonable limits on near-term wind speeds may benefit both parties.

Deck formwork reduces wind loads by:

- Disrupting airflow around the girders, thus reducing the base drag coefficient
- Eliminating drag on leeward girders

It is important for owners, designers, and contractors to understand how the wind load changes as bridges are built. The AASHTO guide specifications for wind loads provide design provisions for wind loads during bridge construction, but minor changes to those provisions could provide time and cost savings with a negligible increase in risk.

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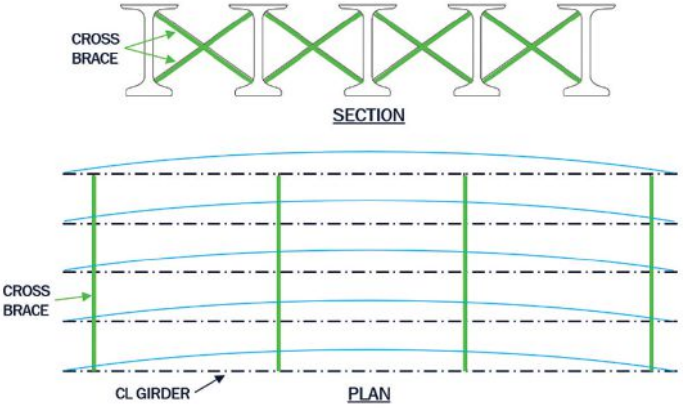
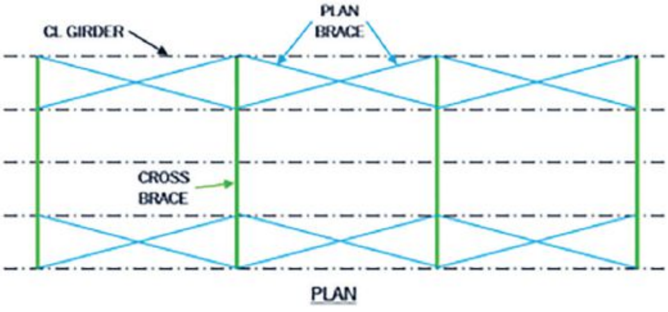
Brian Witte is vice president of construction engineering and Justin Ramer is the construction engineering manager for Parsons in Westminster, Colo.

Figure 5. Typical cross bracing layout (left). Plan bracing (right) is uncommon in precast concrete girder bridges. Figure: Parsons.





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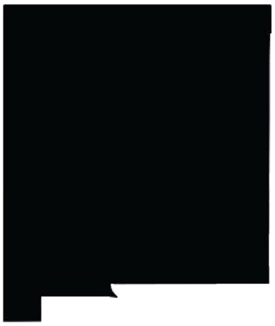

by Kimberly Coleman, New Mexico Department of Transportation

With a current staff of 18 engineers, analysts, and technicians in its design and management sections, the New Mexico Department of Transportation (NMDOT) Bridge Bureau manages an inventory of 2980 state-owned bridges and bridge-size culverts (greater than 20-ft span). Of these, 1140 are prestressed or reinforced concrete girder bridges. The Bridge Bureau also inspects 802 locally owned bridges.

NMDOT's role includes internal design, consultant oversight, construction technical support, emergency damage inspection and recommendations, management of the National Bridge Inspection Standards inspection program, load rating, and oversize and overweight permitting.

NMDOT has a distinctive collection of challenges for bridge construction and maintenance. Many of the state's bridges are in very remote areas, where projects may involve long lead times on delivery and face challenges with construction staffing. New Mexico has a wide range of elevations: from 2800 ft at Red Bluff Reservoir in the southeast to more than 13,000 ft at Wheeler Peak in the northern part of the state. The variations in elevations translate to substantial climate differences: bridges in the southwest desert region experience very hot and dry conditions, where crack prevention during concrete curing is paramount, and bridges in the northern mountain region experience frequent freezing and thawing and applications of deicing salts. In most areas of the state, daily temperatures can swing as much as 50°F, so thermal expansion details are critical for these bridges!

Figure 1. New Mexico's oldest concrete arch bridge carries Bridge Street over the Gallinas River in Las Vegas, N.Mex. It was built in 1909 and is still in service today. Photo: New Mexico Department of Transportation.

Concrete Bridges in New Mexico throughout History

New Mexico has relied heavily on concrete over the years. The state has several notable old concrete bridges that have stood the test of time and remain in service today.

One of New Mexico's oldest in-service concrete bridges is a locally owned concrete arch in central Las Vegas, N.Mex., built in 1909 (**Fig. 1**). This bridge carries Bridge Street over the Gallinas River, which is part of the historic Santa Fe Trail. Even though this bridge has been in service for over 110 years, it is still in fair condition—truly an example of concrete performing to its best advantage!

Another of New Mexico's oldest bridges is in the heart of Santa Fe. This concrete through-truss bridge, dubbed the "Rainbow Bridge," was built in 1920 and carries Grant Avenue over Arroyo de Las Mascaras (**Fig. 2**). This bridge is load posted at 10 tons, but it is still in fair condition and is still performing its intended function.

Figure 2. One of New Mexico's oldest bridges carries Grant Avenue over Arroyo de Las Mascaras in the heart of Santa Fe. The concrete through-truss bridge, dubbed the "Rainbow Bridge," was built in 1920. Photo: New Mexico Department of Transportation.

Figure 3. Two of the New Mexico Department of Transportation's concrete K-frame bridges carry Interstate 40 in Tucumcari, N.Mex. There are eight K-frame bridges in the state. Photo: New Mexico Department of Transportation.

Use of reinforced concrete in New Mexico began around 1912. Multiple-span concrete slab bridges became the predominant bridge type beginning in the 1930s, and this trend held steady until around 1990. Owing to their relatively low construction costs, cast-in-place, reinforced concrete slab bridges are now enjoying a small resurgence in the state's dry arroyos (water-carved gullies or channels that fill and flow seasonally).

New Mexico's multispan, rigid K-frame structures represent an unusual type of reinforced concrete bridge (**Fig. 3**). NMDOT owns six of these bridges, four of which were built in 1980 and 1981 and are in satisfactory condition. Two were built in 1990 and are in good condition. NMDOT looks forward to many more years of use from these bridges.

New Mexico's first prestressed concrete girder bridge, Alameda Boulevard over the Rio Grande, was built in Albuquerque in 1956. It was replaced in 1993 by an adjacent bridge and decommissioned in place to support a multiuse trail.

Prestressed concrete girder bridge construction gained traction in New Mexico in the 1960s, peaking in the 1970s. The pace of this type of construction has held steady since—an average of approximately 150 prestressed concrete girder bridges have been built each decade since the peak of 279 bridges in the 1970s. This is clearly a workhorse bridge type for NMDOT, a trend that will likely continue as the state has three precast concrete producers and no local steel producers. Currently, only one of these in-state producers is casting prestressed concrete girders for highway projects.

NMDOT's first concrete segmental bridges carry the flyover ramps at the interchange of Interstate 25 (I-25) and Interstate 40 (I-40). These eight precast concrete segmental bridges were completed in 2002 and have been performing well. One of NMDOT's challenges with this bridge type is that the enclosed interior cells have become sites for encampments of homeless people, which have presented biohazard and other environmental issues.

In 2021, construction was completed on NMDOT's first cast-in-place concrete segmental bridge, U.S. Route 54 over the Canadian River in Logan, N.Mex., featured in the Winter 2021 issue of *ASPIRE*® (**Fig. 4**). This bridge type was selected because it could be constructed from above, thus surmounting environmental constraints caused by wetlands and endangered fish species in the Canadian River below. The bridge, which was opened in June 2021, was awarded the 2021 American Segmental Bridge Institute's Bridge Award of Excellence and the 2022 American Council of Engineering Companies' Grand Conceptor Award.

Ultra-High-Performance Concrete

NMDOT's experience with ultra-high-performance concrete (UHPC) kicked off in 2008 with a four-phase research project in collaboration with New Mexico State University (NMSU). Phase I of this research began with a literature review on the benefits of UHPC and several preliminary designs for UHPC girder replacements for New Mexico bridges. Phase II included development and compressive-strength testing of a nonproprietary UHPC mixture developed by NMSU using local materials. This concrete achieved compressive strengths in the range of 21 ksi. Phase III involved casting and testing of two production-size UHPC girders. The successful results of these tests convinced NMDOT to proceed with a bridge replacement using UHPC girders. NM 186 over La Union Main Canal near Anthony, N.Mex., built in 2017, is a two-span bridge where one span was constructed using conventional 9.5-ksi precast, prestressed concrete and the second span was constructed using NMSU's nonproprietary, 20-ksi UHPC. Both spans use channel girders for the 24-ft 10-in. spans. The conventional concrete girders are 1 ft 3 in. deep, and the UHPC girders are 1 ft ½ in. deep. All girders contained the same prestressing and mild reinforcement.

The bridge was instrumented with internal and external strain gauges and load tested several times to establish a baseline for future testing and provide comparisons between the behavior of the two concrete types (**Fig. 5**). In Phase IV, NMSU undertook development and testing of nonproprietary UHPC mixtures for joints and overlays. A 1-in.-thick UHPC overlay concrete was

Figure 4. The U.S. Route 54 over Canadian River Bridge was New Mexico's first cast-in-place concrete segmental bridge. Shown here under construction, with form travelers being used for the balanced-cantilever construction. Photo: Malcolm International

applied to L-00012 over I-25 in Socorro, N.Mex. During placement, the UHPC was not adhering well to the deck concrete beneath. This problem may have been caused by difficulty in attaining a true saturated surface-dry condition—the contractor struggled with both too much and too little moisture in different areas of the deck. The nonproprietary joint concrete has not yet been used in a production bridge.

As NMSU's research on nonproprietary UHPC was progressing, NMDOT used proprietary UHPC mixtures on several other projects: one UHPC deck overlay and four precast concrete bridges with UHPC closure joints. New Mexico's most recent precast concrete bridge with UHPC closures is NM 50 over Glorieta Creek. In the 2023 PCI Design Awards, it received the All-Precast Concrete Solution award and an honorable mention for Bridge with a Main Span under 75 ft (**Fig. 6**).

Now that NMDOT and the local contracting community have gained experience and seen success on several UHPC projects, the agency expects to continue using UHPC as an available tool for future projects where greater strength and accelerated construction methods are needed.

Figure 5. Load testing on the NM 186 over La Union Main Canal. This is the New Mexico Department of Transportation's first use of ultra-high-performance concrete (UHPC) for a prestressed concrete girder bridge. One span of the two-span bridge used UHPC, and the other span used a conventional concrete mixture. Photo: New Mexico Department of Transportation.

Accelerated Bridge Construction

Like many other states, New Mexico has ventured into accelerated bridge construction (ABC). NMDOT's use of ABC has been primarily focused on schedule savings that can be realized using prefabricated bridge elements and systems.

NMDOT's first accelerated project was the 28-day construction of a two-span adjacent box-girder bridge carrying Mountain Valley Road over I-40. This bridge was completed in 2005 and features precast concrete abutments and pier caps and precast concrete box girders with a 5-in. topping slab. Another ABC project, the Las Vegas Airport Interchange carrying NM 250 over I-25, was completed in 2014 under a 45-day bridge closure. This bridge was featured in the Winter 2017 issue of *ASPIRE*. NMDOT's most recent ABC project was the previously mentioned seven-week construction of NM 50 over Glorieta Creek.

Emergency Repairs

On occasion, vehicular impacts damage bridges. NMDOT Bridge Bureau staff respond to several bridge strikes and emergencies each year, inspecting damage, coordinating with district staff on necessary lane closures, and providing repair recommendations.

A recent emergency occurred on an interstate flyover ramp in Las Cruces, N.Mex. On the evening of July 11, 2023, a fuel tanker truck tipped on its side, catching fire and spilling burning fuel near the departure abutment. It burned for approximately 80 minutes, causing explosive spalling and strength loss to the deck, concrete bridge rail, and downslope wingwall (**Fig. 7**). NMDOT's emergency repair contractor used hydrodemolition to remove the fire-damaged concrete and recast or patch the damaged components. Repairs were completed and the bridge was reopened to traffic on December 13, 2023.

Figure 6. Installation of ultra-high-performance concrete joints on the NM 50 over Glorieta Creek Bridge. Photo: New Mexico Department of Transportation.

Figure 7. In July 2023, a fuel tanker truck overturned and burned, resulting in fire damage to a concrete bridge deck and barriers. The fire-damaged concrete was repaired or removed and replaced. The structure was reopened five months later. Photo: New Mexico Department of Transportation.

Figure 8. In October 2022, the NM 129 overpass over Interstate 40 was hit by an excavator and all strands were severed on two of the five prestressed concrete girders. One lane was immediately closed and remains closed. Construction to replace the damaged span is anticipated to begin in late 2024. Photo: New Mexico Department of Transportation.

Another source of significant damage has been vehicular collisions with girders. The resiliency and redundancy of concrete girder bridges allow many of these damaged girders to be repaired. NMDOT has used strand couplers, cementitious patch materials, and sometimes carbon-fiber wrap to quickly put the damaged girders back into serviceable condition. However, some damages defy repair. In October 2022, the NM 129 overpass over I-40 was hit by an excavator, which severed all strands on two of the five girders over the eastbound lanes (**Fig. 8**). NMDOT staff immediately closed the lane carried by the two damaged girders, and the bridge is still restricted to one lane in this span. A design project is currently underway to replace the damaged span, with construction anticipated to begin in late 2024.

Conclusion

NMDOT has a long and successful history of building and maintaining concrete bridges, one that the agency hopes to build on and continue to improve in the years to come.

Kimberly Coleman is a bridge design engineer and design unit manager at the New Mexico Department of Transportation (NMDOT) in Santa Fe. Also contributing to the article from NMDOT were Ben Najera, bridge design section manager; Jeff Vigil, bridge management section manager; Gary Kinchen, bridge load rating engineer; and Carlos Vigil, bridge engineering technician IV.

Professing My Perspective: It's Evolutionary

by Dr. Jill Walsh, Saint Martin's University

In 2002, fresh out of the University of California in sunny San Diego, with my PhD in hand, I found myself weighing the urge to teach against my lack of experience. Although I had built and tested 40%-scale bridge models and completed rigorous courses, that alone wasn't enough for me to feel good about hanging a "Professor Walsh" placard outside a lecture hall door. So, I went to work with T. Y. Lin International, where I was fortunate to learn from and work with some of the best bridge engineers and contractors in the world on exciting and challenging projects. I did this for more than a decade, working on teams that built the Mike O'Callaghan–Pat Tillman Memorial Bridge spanning the Colorado River between Arizona and Nevada and the Port Mann Bridge in Vancouver, British Columbia.

But by 2015, I was ready to make my way back to academia and accepted an assistant professor position at Saint Martin's University, a small liberal arts college, in Lacey, Wash. With my hard-won knowledge of analysis and concepts I had applied in the field, I was ready to share with students what it meant to work hard and be self-sufficient, and that there is absolutely no crying in engineering.

That same year, the first members of the so-called Generation Z were turning 18 and entering college. Gen Z is defined by birth dates between 1997 and 2012; the cohort is currently between 12 and 27 years old. Those who came before them have often mischaracterized Gen Zers as being lazy and have claimed they had it too easy. Because Gen Z is the first generation to be fully digital, there was plenty of anecdotal evidence to support this view.

Gen Z and a New Way to Learn

In her book *Gen Z, Explained: The Art of Living in a Digital Age*,[1] Stanford University professor Roberta Katz and her coauthors explain that Gen Z has only known a world of endless information, having never lived a life without the internet. They state, "Every generation inherits a world they did not make, but Gen Zers are especially concerned about what they face, from faltering institutions to increasing inequality to climate change. They have no choice but to turn to the tools with which they have grown up—digital technologies and networks—to try to solve these problems. They are aware that the digital technology that causes problems might also offer some of the solutions."

In addition to Gen Z's technological finesse, the researchers found Gen Zers to be highly collaborative and social. Members of Gen Z strive for diverse communities and care deeply about others. They have access to all the information in the world and technological skills to "work smarter." But this mantra is potentially dangerous if context and understanding are lacking. With artificial intelligence poised to eliminate many of the procedural aspects of engineering, new engineers need to be able to provide meaningful input and look critically at the output.

Dr. Walsh on a site visit in 2009. All Photos: Jill Walsh.

Generation X and the Old Way to Learn

Generation X includes anyone born between 1965 and 1980. Like any proud, flannel-wearing Gen Xer, I took pride in my latchkey-kid status. While we didn't use punch cards in college, we did use Lotus 1-2-3 and took FORTRAN programming. My undergraduate professors wrote equations on chalkboards spanning the width of one wall. Reaching the end of the board meant returning to the starting point and erasing the previous equations—a learning environment that would seem otherworldly to today's students.

By the mid-1990s, Netscape was the best browser to search the World Wide Web. By graduate school, I was saving Excel files on a floppy disk (the object on which the Microsoft Save icon is based). But we still wrote our

St. Martin's University 2018 graduation. From left to right: Clarinda Marion, Will Miller, the author, Micaylla Young, Cameron Reece, Dr. Floraliza Bornasal, Dr. Jae Chung.

2024 Future Engineers. From left to right: Abraham Debasu, Edward Suppes, Eli Eldridge, Andrew Milholland, Marcus Hurley, Jeffrey Lowe.

homework on paper and waited a week for feedback. We still scrolled through microfiche for historical journal articles. That's how you learned, and it was good enough for us.

Boomers and Gen X

At T. Y. Lin, I depended on the experience and knowledge of my supervisors and reveled in collaborations with coworkers. Engineers develop an appreciation and understanding of design details through experience. We understand the evolution from allowable stress design (ASD) to load- and resistance-factor design (LRFD)—and how a quick ASD calculation can provide a nice starting point or gut check. We know that "Chapter 17: Anchoring to Concrete" of the American Concrete Institute's *Building Code Requirements for Structural Concrete* (ACI 318-19) *and Commentary* (ACI 318R-19)[2] made its first appearance as Appendix D to ACI 318-02 and received considerable review and expansion following the 2006 collapse of the ceiling panels in the Ted Williams Tunnel in Boston, Mass. We know that current ductile design details evolved from work presented in Thomas Paulay's and Nigel Priestley's 1992 book, *Seismic Design of Reinforced Concrete and Masonry Buildings*.[3] The generational passing of engineering knowledge is vital for efficient, effective, and safe structures. Structural history dictates the structural future. The Mike O'Callaghan–Pat Tillman Memorial Bridge girder-to-concrete pier cap connections would not be the same if not for experiences learned during the construction of Missouri's Creve Coeur Lake Memorial Bridge.

Gen X Teaching Gen Z

My educational background contributed to my "No, I will not save the lecture slides for you" mentality when I started teaching. I now share skeleton slides before class and post slides with class notes afterward. We work through problems together in class. This is a simple example of adapting to Gen Z's way of learning. I find myself increasingly impressed by my students and no longer feel it is my job to "toughen" them up. COVID-19, climate change, and the speed of technological developments have done that.

Fortunately, Gen Z is a generation of highly adaptive learners who come from diverse backgrounds and are equipped with creative solutions and pragmatic optimism. And while they have access to endless historical information, there is no substitute for the retained knowledge and comprehension that can only be found in the work environment, on a project, or in direct collaboration with a supervisor. And those who are lucky enough to work alongside this new generation of engineers? Get ready to watch them do what that Microsoft floppy disk icon does best: save our work.

"Help Me Change the World"

In his last message in 1941, Boy Scout founder Robert Baden-Powell told the scouts, "Try and leave this world a little better than you found it."[4] I'm not sure my generation can claim we heeded his advice. Gen Z has inherited climate change, resource depletion, gentrification creep, and the rapid rise of artificial intelligence.

One of my students wore a sweatshirt with the phrase "Help me change the world." If I had to identify one group capable of changing the world, it would be engineers. From the engineering accomplishments of the Brooklyn Bridge to the ingenuity of accelerated bridge construction and the James Webb Space Telescope launched in 2021, engineers have repeatedly proved that the impossible is possible.

Now imagine combining Gen Z's energy, technical efficiency and pragmatic optimism with veteran engineers' experience, knowledge, and historical wisdom. Together, they will build a bridge between generations that changes the world.

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Approved Changes to the Ninth Edition *AASHTO LRFD Bridge Design Specifications:* Design of Segmental Bridges

by Dr. Oguzhan Bayrak, University of Texas at Austin

Article 5.12.5—Segmental Concrete Bridges of the ninth edition of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] was originally based on the AASHTO *Guide Specifications for Design and Construction of Segmental Concrete Bridges*.[2] AASHTO's Committee on Bridges and Structures Agenda Item 27, Working Agenda Item 218, will update many parts of this article and other articles related to segmental concrete bridges in the forthcoming 10th edition of the AASHTO LRFD specifications.[3] Selected approved updates are as follows:

- The 10th bullet item in Article 3.4.1—Load Factors and Load Combinations will be revised to read as follows:
  - *Service III – Load combination for longitudinal analysis relating to flexural tension* ~~*and principal tension in the webs of prestressed concrete superstructures*~~ *with the objective of crack control.*
- The 18th paragraph of Article C3.4.1 will be deleted to streamline the commentary.
- A new definition will be added to Article 5.2, as follows:
  Diabolo—A formed void in a concrete deviation saddle or diaphragm in a shape to align and direct an external tendon through the horizontal and vertical tendon profile required for the design.
- Article 5.4.6.3 will be revised to read as follows:
  5.4.6.3—External Tendons Passing through Deviation Saddles
  External tendons passing through deviation saddles shall utilize either of the following details:
  - *Galvanized rigid steel pipe ducts*
  - *Diabolos*

  The minimum tendon radius at deviation saddles shall be as large as permitted by the geometry of the tendon and deviation saddle but, unless verified by testing, shall not be less than:

  $$R_{min,d} = 0.306\sqrt{f_{pu}}A_{ps} \geq 6.6\,ft \qquad (5.4.6.3\text{-}1)$$

  where:

  $R_{min,d}$ = *minimum tendon radius at deviation saddle (ft)*

  f_{pu} = *specified tensile strength of prestressing steel (ksi)*

  A_{ps} = *area of prestressing steel (in.²)*

  To utilize a smaller radius than specified by this article, the testing specified by Article 10.3.2.2 of the AASHTO LRFD Bridge Construction Specifications *for rigid pipe duct and plastic ducts through diabolos and Article 10.8.3 of the* AASHTO LRFD Bridge Construction Specifications *for plastic ducts through diabolos shall be performed to verify the adequacy of the proposed details.*

  The galvanized rigid steel pipe ducts in the deviation saddles shall meet the requirements set forth in Article 10.8.2, and the external plastic tendon ducts passing through the deviation saddles shall meet the requirements set forth in Article 10.8.3 of the AASHTO LRFD Bridge Construction Specifications.
- Commentary to Article 5.4.6.3 (C5.4.6.3) will be added, as follows:
  C5.4.6.3
  The minimum tendon radius specified by Article 5.4.6.3 is similar to the minimum radii recommended for external tendons in [Table 6-2 of] *the U.S. Department of Transportation Publication No. FHWA-HIF-19-067,* Replaceable Grouted External Post-Tensioned Tendons, *October 2019:*

  [Table 6-1, at bottom, from the same publication] *also recommends the following minimum radii and tangent lengths at anchorages:*

Tendon Size	Minimum Radius at Deviators (feet)
7-0.6″	6.6
12-0.6″	8.2
15-0.6″	9.0
19-0.6″	9.8
22-0.6″	10.7
27-0.6″	11.5
31-0.6″	12.3

Tendon Size	Minimum Radius at Anchorages (feet)	Minimum Tangent Length at Anchorages (feet)
7-0.6″	9.8	2.5
12-0.6″	11.5	3.3
15-0.6″	12.3	3.3
19-0.6″	13.1	3.9
22-0.6″	13.9	3.9
27-0.6″	14.8	4.3
31-0.6″	15.6	4.8

- The third paragraph in Article 5.8.4.4.2—Bearing Resistance will be revised to read as follows:
The full bearing plate may be used for A_g *and the calculation of* A_b *if the plate material does not yield at the factored tendon force, taken as 1.2 times the maximum jacking force in accordance with Article 3.4.3.2, and the slenderness of the bearing plate,* n/t, *shall satisfy:*
- The associated (Eq. 5.8.4.4.2-4) remains unchanged. The list of parameters after the third paragraph in Article 5.8.4.4.2 will be revised to read as follows:
n = *projection of bearing plate beyond the wedge hole or wedge plate, as appropriate (in.)*
f_b = *the factored tendon force, divided by the effective net area of the bearing plate,* A_b *(ksi)*
- The following paragraph will be added to the end of Article C5.9.2.3.3—Principal Tensile Stresses in Webs:
The principal tension calculation methods in Article 5.9.2.3.3 reflect the standard practice of including only the shear and normal stresses in the computation of the principal stresses. While these methods do not consider the effect of flexural stresses due to transverse moments on the calculation of the principal stresses, they have been shown to be adequate for the design of well-proportioned box girder bridges in conjunction with using the principal stress limits in this specification. The designer should be aware that flexural stresses due to transverse moments do affect principal stresses and may want to consider their inclusion in the principal stress calculation for atypically proportioned box girder bridges. The principal tensile stress limit in this specification does not strictly apply if flexural stresses are included in the principal stress computation.
- The second paragraph of Article 5.12.5.1—General (under Article 5.12.5—Segmental Concrete Bridges) will be revised to read as follows:
The method and schedule of construction assumed for the design shall be shown in the contract documents. Temporary supports required prior to the time the structure, or component thereof, is capable of supporting itself including loads and sequence in construction, shall also be shown in the contract documents.
- The first paragraph of Article C5.12.5.1 will be revised to read as follows:
For segmental construction, superstructures of single or multiple-cell box sections are generally used. Segmental construction includes construction by free cantilever, span-by-span, incremental launching, or other methods using either precast or cast-in-place concrete segments which are connected together to produce either continuous or simple spans.
- The first paragraph of Article 5.12.5.2.3—Analysis of the Final Structural System will be revised to read as follows:
The final structural system shall be analyzed for redistribution of construction-stage force effects due to internal deformations from creep and shrinkage and changes in support and restraint conditions, including accumulated locked-in force effects resulting from the construction process.
- Article 5.12.5.3.2—Construction Loads will be revised, as follows:
WS = *horizontal wind load on structures in accordance with the provisions of Section 3. The wind speed associated with load combinations e and f in Table 5.12.5.3.3-1 and the wind speed associated with load combinations c and d in Table 5.12.5.3.3-1 shall be as determined by the Owner (ksf)*
A = *static weight of precast segment being handled for precast cantilever construction or the empty weight of the form-traveler being utilized for cast-in-place cantilever construction (kip)*
AI = *dynamic response due to accidental release or application of a precast segment load, empty form-traveler load or other sudden application of an otherwise static load to be added to the dead load; in lieu of a dynamic analysis, may be taken as 100 percent of load* A *(kip)*
- The eighth paragraph of Article C5.12.5.3.2 will be revised and additional explanation will be provided, as follows:
The following information is based on some past experience and could be considered for preliminary design. Form-travelers for cast-in-place segmental construction for a typical two-lane bridge with 15.0 to 16.0 ft segments may be estimated to weigh 160 to 180 kips. The weight of form-travelers for wider double-celled box sections may range up to approximately 280 kips. Consultation with contractors or subcontractors experienced in free cantilever construction, with respect to the specific bridge geometry under consideration, is recommended to obtain a design value for form-traveler weight.
Using wind speeds of 0.75 of the speed used for the in-service Strength III limit state for load combinations c and d and 70 mph for load combinations e and f is a reasonable approximation of wind loads that would have resulted from past practice using the AASHTO LRFD Bridge Design Specifications *prior to the change from fastest mile wind speed to 3-second gust wind speed. ASCE 37 can also help give guidance for wind loads during construction.*
Cast-in-place segments are typically supported by form-travelers. Accidental release may involve the release of the empty form-traveler. Accidental release may also involve failure of the supports for the bottom soffit form during segment casting, thereby releasing the bottom slab form and working platform, as well as the bottom slab and web concrete. In the worst case, accidental release may involve failure of the entire form-traveler and all newly cast segment concrete. The weight of the empty form-traveler is the minimum load that should be included in AI. *Note that using 100 percent of the weight of the empty form-traveler for* AI *is a practice that has been successfully utilized in France without collapse of a cantilever. Owners seeking a further reduction of risk could consider including the weight of some segment concrete in* A *and* AI.
For precast segments being lifted by a beam and winch or deck-mounted crane, and CIP [cast-in-place] segments being supported by form-travelers, the dynamic effect of an accidental release is an upward rebound. For precast segments being lifted by a ground-based crane where the segment could be above the cantilever, the dynamic effect is a downward impact force from the segment being suddenly released during lifting.
- The third paragraph of Article 5.12.5.3.3—Construction Load Combinations at the Service Limit State will be revised to read as follows:
The distribution and application of the individual erection loads appropriate to a construction phase shall be selected to produce the most unfavorable effects. The compressive stress in

concrete during construction shall not exceed $0.6\phi_w\sqrt{f'_c}$, *where* f'_{ci} *is the design concrete compressive strength at the time of load application or transfer of prestress. The value for* ϕ_w *shall be calculated as described in Article 5.9.2.3.2a.*

- New commentary Article C5.12.5.3.3, will be added, as follows:
  C5.12.5.3.3
  Table 5.12.5.3.3-1 was developed primarily for balanced cantilever construction but provides a reasonable basis for load combinations for other segmental construction methods. When applied to construction methods other than balanced cantilever construction, loads specific to balanced cantilever, such as DIFF, U *and* WUP, *may be disregarded.*
  The compressive stress limit of $0.6\phi_w\sqrt{f'_{ci}}$ *is specified during construction of segmental bridges, as opposed to the limit of* $0.65f'_{ci}$ *contained in Article 5.9.2.3.1a. This is due to the uncertainty associated with construction loads.*

- Article 5.12.5.3.4 will be revised, as follows:
  5.12.5.3.4—Construction Load Combinations at Strength and Extreme Event Limit States
  5.12.5.3.4a—Construction Load Combinations at the Strength Limit State
  The factored resistance of a component shall be determined using resistance factors specified in Article 5.5.4.2. The following components shall be evaluated for construction loads at the Strength I, III and V limit states:
  - *Prestressed or conventionally reinforced substructures*
  - *Prestressed or conventionally reinforced segmental superstructures*

  The Strength I, III and V load combinations from Table 3.4.1-1 shall apply with the load factors in the table and as modified by this article. The loads DIFF, CEQ *and* IE *shall be included and factored with* γ_p *for* DC. *The load* WUP *shall be included with* WS. *The load* CLL *shall be included and used in place of* LL. *The load* WE *shall be included with load factors of 0.9 and 0.4 for the Strength III and Strength V load combinations, respectively. The wind speeds for* WS *associated with the Strength III and Strength V load combinations shall be as determined by the Owner.*

- Article C5.12.5.3.4a will be revised to read as follows:
  C5.12.5.3.4a
  Using a load factor of 1.25 for construction equipment loads for segmental construction, such as erection gantries, cranes supported by the structure and segment transporters is reasonable as opposed to the 1.5 load factor specified in Article 3.4.2 for construction loads. This is because construction equipment loads are well known or included in the plans for the construction method assumed for design. Smaller miscellaneous construction loads are included in the CLL *allowance.*
  Using load factors of 1.0 with wind speeds of 0.95 of the speed used for the in-service Strength III limit state for the construction Strength III load combination, and 75 mph for the construction Strength V load combination are reasonable approximations of wind loads that would have resulted from past practice using the AASHTO LRFD Bridge Design Specifications *prior to the change from fastest mile wind speed to 3-second gust wind speed. ASCE 37 can also help give guidance for wind loads during construction.*
  5.12.5.3.4b—Construction Load Combinations at the Extreme Event Limit State
  In accordance with Article 1.3.2.1, the resistance factor for concrete design shall be 1.0. The loads DIFF *and* CLL *shall be placed to maximize the force effects.*
  - *For maximum force effects:*
    $$\sum \Upsilon Q = 1.1\,(DC + DIFF) + 1.3\,(CEQ + CLL) + A + AI$$
    (5.12.5.3.4b-1)
  - *For minimum force effects:*
    $$\sum \Upsilon Q = DC + DIFF + CEQ + CLL + A + AI$$
    (5.12.5.3.4b-2)

  In addition to the superstructure, the following substructure elements shall consider the dynamic response (AI)*:*
  - *Temporary supports and their foundations.*
  - *Piers, including the pier to footing or pier to monoshaft connection.*
  - *Above grade or buried footings. The design shall be based on pile or shaft force effects resulting from an analysis of the dynamic response, regardless of whether the static geotechnical resistance of the piles or shafts is exceeded.*
  - *Piles and shafts supporting footings where the ground or mudline is less than one diameter of a foundation element above the bottom of footing, regardless of whether the static geotechnical resistance of the piles or shafts is exceeded. The structural resistance of the piles or shafts shall be checked from the bottom of the footing to the first points of maximum moment and shear below the ground or mudline.*
  - *The structural resistance of monoshafts, even if below the ground or mudline, shall be checked to the first points of maximum moment and shear below the ground or mudline.*

- Article C5.12.5.3.4b will be revised, as follows:
  C5.12.5.3.4b
  The construction load combinations evaluated at the extreme event limit state are intended to address a low probability event. This extreme event limit state evaluation does not replace the evaluation of construction loads under the service limit state or strength limit state.

- The first paragraph of Article 5.12.5.3.6—Creep and Shrinkage will be revised, as follows:
  Creep and shrinkage shall be determined in accordance with Article 5.4.2.3. Forces and stresses shall be determined for redistribution of restraint stresses developed by creep and shrinkage deformations that are based on the assumed construction schedule as stated in the contract documents.

- The fourth paragraph will be revised and new discussion added to Article C5.12.5.3.8d (Torsional Reinforcement), as follows:
  Unlike solid sections, when designing the webs of segmental bridges, the shear and torsion reinforcement should be directly added together. Reinforcement for transverse bending in the webs and other box girder elements should be accounted for in the total reinforcement demand. Standard practice for typical segmental highway bridges is to combine the shear and torsion reinforcement, and transverse bending reinforcement in each box girder element so that the total reinforcement on each face of each web or flange exceeds the greater of:
  - $1.0(A_{sv}+A_{st}) + 0.5A_{sb}$ *(C5.12.5.3.8d-1)*
  - $0.5(A_{sv}+A_{st}) + 1.0A_{sb}$ *(C5.12.5.3.8d-2)*

  where:
  A_{sv} = *area of required shear reinforcement for one face of a*

web within a distance s *(in.²)*

A_{st} = *area of required torsion reinforcement for one face of an exterior web or flange within a distance* s *(in.²)*

A_{sb} = *area of required reinforcement due to transverse bending for one face of a web or flange within a distance* s *(in.²)*

The equations above acknowledge that the maximum shear and torsion effect is unlikely to occur concurrently with maximum transverse bending. However, the engineer must consider if this condition is applicable to the structure in design. Examples where direct combination of the reinforcement are applicable include single lane ramp structures and transit structures.

- Articles 5.12.5.3.9a and 5.12.5.3.9b (within Article 5.12.5.3.9—Provisional Post-Tensioning Ducts and Anchorages) will be revised to read as follows:
  5.12.5.3.9a—General
  Provisions for adjustments of prestressing force to compensate for unexpected losses during construction specified in the contract documents.
  5.12.5.3.9b—Bridges with Internal Ducts
  Provisional duct or anchorage capacity shall accommodate increases to both positive moment and negative moment post-tensioning forces. The increases shall be taken as not less than five percent of the total post-tensioning forces specified in the contract documents.
  For continuous bridges, positive moment force adjustment need only be provided for the middle 50 percent of each span.
  Provisional capacity shall be uniformly distributed to each web and located symmetrically about the bridge centerline. Anchorages shall be distributed uniformly at three-segment intervals along the length of the bridge.
  Utilized and unutilized provisional ducts shall be grouted at the same time as other ducts in the span.

- Article C5.12.5.3.9b will be revised, as follows:
  Provisional post-tensioning duct and/or anchorage capacity permit the introduction of additional prestressing force to compensate for installation or stressing problems that might arise during construction.
  Excess capacity may be provided by use of oversize ducts and oversize anchorage hardware at selected anchorage locations well distributed along the length of the bridge.

- Article 5.12.5.3.9c will be revised to read as follows:
  5.12.5.3.9c—Provision for Future Load
  Provision shall be made for installation and stressing access and for anchorage attachments, pass-through openings, and deviation saddle attachments to permit future addition of corrosion-protected unbonded external tendons located inside the box section symmetrically about the bridge centerline. Diaphragm and deviation saddles shall be designed to accommodate the forces from the future tendons. At a minimum one future tendon for exterior webs and two future tendons for interior webs shall be provided. These tendons shall have a minimum size equivalent to 12 0.6-in. diameter strand tendons. The future tendons shall satisfy one of the following requirements:
  - *Future tendons shall provide a post-tensioning force of not less than ten percent of the primary positive moment and negative moment post-tensioning forces.*
  - *Future tendons shall be designed to increase the superstructure resistance for flexure, shear, and torsion for the in-service Strength I, Service I and Service III load combinations to accommodate the combined effect of the following load increases:*
    –Ten percent DW
    –Ten percent bridge railing dead load
    –Ten percent LL + I
    –Ten percent CR *and* SH

  Any extra design resistance in the original design can be utilized to resist the specified load increases, such that the initial and future post-tensioning together meet the increased load requirements.

- Article C5.12.5.3.9c will be revised, as follows:
  This provides for future addition of external unbonded post-tensioning tendons.
  The first requirement specifies an addition of future tendons to provide for a force of ten percent of the primary positive moment and negative moment post-tensioning forces and does not require any additional analysis.
  The second requirement provides for a refinement of the future post-tensioning system by designing for a ten percent increase in the specified loads. Relative to the first option, this refinement allows for a reduction in future post-tensioning forces in regions where there is already extra capacity. An example is a balanced cantilever bridge constructed with form-travelers or beam and winches. The post-tensioning required to support the free cantilevers along with the equipment loads can be more than what is required for the in-service structure. Therefore, the future post-tensioning tendons for negative moment at the piers required to resist specified load increases can possibly be reduced from a ten percent increase in the negative post-tensioning force.
  Typically, future post-tensioning tendons are draped external tendons that are close to the bottom slab near midspan and anchor in the pier diaphragms as high as possible. The tendons typically lap through the pier diaphragms with anchorages located on opposite sides of the diaphragm. Provision for larger amounts of post-tensioning might be developed, as necessary, to carry specific amounts of additional load as considered appropriate for the structure.

- The third paragraph will be revised and a new fifth paragraph will be added to the end of Article C5.12.5.3.11a—Minimum Flange Thickness (within Article 5.12.5.3.11—Box Girder Cross Section Dimensions), as follows:
  Where the clear span between the faces of webs is 15.0 ft or larger, transverse prestressing of the top deck is typically utilized. However, prestressing may also be utilized to improve deck durability (regardless of span length) at the Owner's discretion. To ensure that these benefits are realized, Owners need to ensure that project specifications explicitly state when transverse prestressing of the deck is required for other than structural purposes.
  For most existing segmental bridges, the cantilever length of the top flange is less than 0.60 of the interior clear span of the top flange. When the cantilever exceeds 0.45 of the interior span, designers should consider investigating top flange deflections during casting and erection and the need for partial post-tensioning of the top flange for geometry control.

- Article 5.12.5.3.11c—Length of Top Flange Cantilever will be deleted and the current Article 5.12.5.3.11d—Overall Cross Section Dimensions will be renumbered.

- The second paragraph of Article C5.12.5.4.1 (the General portion of Article 5.12.5.4—Types of Segmental Bridges) will be revised to read as follows:
  Bridges erected by balanced cantilever or progressive placement normally utilize internal tendons. Bridges built with erection trusses may utilize internal tendons, external tendons, or combinations thereof. Due to considerations of segment weight, span lengths for precast segmental box girder bridges, except for cable-stayed bridges, generally do not exceed 400 ft.
- The second paragraph of Article 5.12.5.4.2—Details for Precast Construction will be revised, as follows:
  Multiple small-amplitude shear keys at match-cast joints in webs of precast segmental bridges shall extend over as much of the web as is compatible with other details. Details of shear keys in webs should be similar to those shown in Figure 5.12.5.4.2-1. Alignment keys shall also be provided in top and bottom slabs. Keys in the top and bottom slabs may be larger single-element keys.
- The fourth paragraph of Article 5.12.5.4.2 will be deleted.
- The fifth paragraph of Article 5.12.5.4.2 will be revised, as follows:
  Where an epoxy joint is specified, a temporary or permanent prestressing system shall provide a minimum compressive stress of 0.030 ksi and an average stress of not less than 0.040 ksi across the joint until the epoxy has cured. If the segment or segments being erected are supported by the prestressing system, the stresses due to the prestressing and the weight of the segment being erected shall be combined and the same stress limits apply.
- A new second paragraph will be added and the third paragraph will be revised in Article C5.12.5.4.2, as follows:
  To aid in geometry control, the stress across the joint should be as uniform as practical until the epoxy has cured. Having a difference between maximum and minimum compressive stress of no more than 0.060 ksi is recommended.
  Small-amplitude shear keys in the webs are less susceptible to stress concentrations and construction damage, which will result in loss of geometry control, than larger single-element keys. Alignment keys in the top and bottom flanges are less susceptible to such damage.
- The third paragraph of Article 5.12.5.4.3—Details for Cast-in-Place Construction will be revised, as follows:
  Diaphragms shall be provided at abutments, piers, hinge joints, and bottom flange angle points in structures with straight haunches. Diaphragms shall be substantially solid at piers and abutments, except for access openings and utility holes. Diaphragms shall be sufficiently wide as required by design.
- A new first paragraph to Article C5.12.5.4.4—Cantilever Construction will be added, and the fourth paragraph will be revised, as follows:
  Permanent or temporary longitudinal strand or bar tendons satisfy the requirement to anchor a minimum of two tendons in each segment.
  Lengths of segments for free cantilever construction typically range between 8.0 and 18.0 ft. Lengths vary with the construction method, the span length, and location within the span.
- The second paragraph of Article 5.12.5.4.5—Span-by-Span Construction will be revised, as follows:
  Forces and stresses due to the changes in the structural system, in particular the effects of the application of a load to one system and its removal from a different system, shall be accounted for. Redistribution of such forces and stresses by creep shall be taken into account and allowance made for possible variations in the creep rate and magnitude.
- The first and second paragraphs of Article 5.12.5.4.6a (the General portion of Article 5.12.5.4.6—Incrementally Launched Construction) will be revised to read as follows:
  - *Stresses under all stages of launching shall not exceed the limits specified in Article 5.12.5.3.3.*
  - *Provision shall be made to resist the frictional forces on the substructure during launching and to restrain the superstructure if the structure is launched down a gradient.*
- The second paragraph of Article C5.12.5.4.6a will be revised, as follows:
  For determining the critical frictional forces, the friction on launching bearings should be assumed to vary between 0 and 4 percent, whichever is critical. The upper value may be reduced to 3.5 percent if pier deflections and launching jack forces are monitored during construction. These friction coefficients are only applicable to bearings employing a combination of virgin PTFE and stainless steel with a roughness of less than 1.0×10^{-4} in.
- Article 5.12.5.4.6b—Force Effects Due to Construction Tolerances will be revised to read as follows:
  Force effects due to permissible construction tolerances shall be considered, both during construction and for the in-service structure. Unless otherwise specified in the contract documents, the tolerances shall be taken as:
  - *In the longitudinal direction between two adjacent bearings .... 0.2 in.*
  - *In the transverse direction between two adjacent bearings .... 0.1 in.*
  - *Between the fabrication area and the launching equipment in the longitudinal and transverse direction .... 0.1 in.*
  - *Lateral deviation at the outside of the webs .... 0.1 in.*

  The horizontal force acting on the lateral guides of the launching bearings shall be taken as less than one percent of the vertical support reaction.
  For design of the in-service structure, locked-in force effects from construction tolerances, EL, *shall be included in load combinations according to Table 3.4.1-1. For forces and stresses during construction, one-half the effects of construction tolerances and one-half the effects of temperature gradient shall be added together and applied as load* TG *in Table 5.12.5.3.3-1. Concrete stresses due to the load combinations in Table 5.12.5.3.3-1 shall not exceed those specified in Article 5.12.5.3.3.*
- A new article, C5.12.5.4.6b, will be added, as follows:
  C5.12.5.4.6b
  The designer can reduce tolerances through construction details, in which case the force effects may be reduced accordingly. Permanent bearings grouted in place after launching has been completed is an example of a construction detail to alleviate tolerance force effects.
- The third and fourth paragraphs of Article 5.12.5.4.6c—Design Details will be revised, as follows:
  The straight tendons required for launching shall be sufficient to meet the service and strength limit state requirements of this specification. Not more than 50 percent of the tendons shall be

coupled at one construction joint. Anchorages and locations for the straight tendons shall be designed for the concrete strength at the time of tensioning.

The faces of construction joints shall be provided with keys or a roughened surface with a minimum roughness amplitude of 0.25 in. Bonded nonprestressed reinforcement shall be provided longitudinally and transversely at all exterior concrete surfaces. The longitudinal reinforcement shall run continuously through the segments and joints. Longitudinal reinforcement shall not be spliced at joints.

- A new paragraph will be added to the Commentary Article C5.12.5.4.6c, as follows:
  Minimum reinforcement of the equivalent of No. 4 bars spaced at 5.0 in. both longitudinally and transversely on all exterior concrete surfaces of the girder, with the longitudinal bars running across the joints has been recommended in past editions of this specification. Splices of the longitudinal bars may be located just to one side of joints such that no length of the splice is running through the joints.
- The fourth paragraph of Article 5.12.5.5—Use of Alternative Construction Methods will be revised to read as follows:
  For the value engineering, the Contractor shall provide a complete set of design computations and revised contract documents. The value engineering redesign shall be prepared by a Professional Civil Engineer or Structural Engineer experienced in segmental bridge design. Upon acceptance of a value engineering redesign, the Professional Civil Engineer or Structural Engineer responsible for the redesign shall become the Engineer in Responsible Charge. Based upon the jurisdiction in which the project resides, the Owner shall specify whether a Professional Civil Engineer or Structural Engineer is required for the redesign.
- A new second paragraph to Article C5.12.5.5 will be added, as follows:
  It is recommended that the Engineer in Responsible Charge for the value engineering redesign be licensed and that the working drawings and calculations are signed and sealed accordingly.

Conclusion

The segmental bridge design provisions of the ninth edition AASHTO LRFD specifications will be revised to be more consistent with the remainder of Section 5, be more current with the remaining provisions, and reflect more current practice. The cost implications of the revisions summarized in this article are anticipated to be minimal, if any.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications.* 9th ed. Washington, DC: AASHTO.
2. AASHTO. 1999. *Guide Specifications for Design and Construction of Segmental Concrete Bridges.* 2nd ed., with 2003 Interim Revisions. Washington, DC: AASHTO.
3. AASHTO. Forthcoming. *AASHTO LRFD Bridge Design Specifications.* 10th ed. Washington, DC: AASHTO.

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- AASHTO. 2017. *AASHTO LRFD Bridge Construction Specifications.* 4th ed., with 2020 Interim Revisions. Washington, DC: AASHTO.
- American Society of Civil Engineers (ASCE). 2015. *Design Loads on Structures during Construction.* ASCE/SEI 37-14R (2019). Reston, VA: ASCE.
- Ledesma, T. 2019. *Replaceable Grouted External Post-Tensioned Tendons.* FHWA-HIF-19-067. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/bridge/concrete/hif19067.pdf.

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

IN THIS ISSUE

https://www.sgh.com/insights
This is a link to the Simpson Gumpertz & Heger (SGH) website, where videos and publications are available to advance the state of the profession and improve the understanding of the built environment. SGH believes in the pursuit of lifelong learning and is profiled in the Focus article on page 6.

https://www.pci.org/PCI/Education/Leadership_PCI.aspx
Leadership PCI is described in the Perspective article on page 10 as a program that can promote engagement and leadership within the concrete bridge industry. The webpage at this link provides information on the program and a summary video.

https://www.pci.org/SustainabilityResources
https://www.cement.org/sustainability
The Perspective on page 10 discusses the leadership needed in our industry and workforce to drive sustainable practices in the concrete industry. These links lead to resources from PCI and the Portland Cement Association on the complex issues of sustainability and life-cycle analysis.

https://www.pci.org/PCI/Project_Resources/Project_Profile/Project_Profile_Details.aspx?ID=220335
This is a link to a project profile of the Governor Mario M. Cuomo Bridge connecting New Jersey and New York, which received the 2019 PCI Design Awards Transportation Award for Best Special Solution. This bridge, which included approximately 6000 full-depth deck panels, is mentioned in the Focus article about SGH on page 6. SGH worked with the precaster to develop the concrete mixture, maximize production efficiency, and perform special laboratory testing.

https://northsplit.com
The North Split Interchange in Indianapolis, Ind., where Interstates 65 and 70 merge and overlap, is the subject of the Project article on page 16. This is a link to the project website. Its News/Features tab provides access to photos, videos, local business information, and "Women of the North Split" profiles.

https://www.kenmorewa.gov/our-city/projects/completed-projects/west-sammamish-river-bridge-replacement-project
This is a link to a webpage with a project overview and construction highlight videos for the new West Sammamish River Bridge in Kenmore, Wash., which is featured in the Project article on page 20. The 600-ft-long, five-span structure with prestressed concrete tub girders replaced a structurally vulnerable bridge.

https://nap.nationalacademies.org/read/25478/chapter/2
The Concrete Bridge Technology article on page 30 provides insight into the engineering of bridge demolition. The National Cooperative Highway Research Program Synthesis 536 publication, *Bridge Demolition Practices*, available via this link, provides an overview of the "state of the industry" in engineering for bridge demolition. The report also contains results from a survey of 42 state departments of transportation.

https://highways.dot.gov/research/structures/ultra-high-performance-concrete/deployments
This link leads to an interactive map showing projects that have featured ultra-high-performance concrete (UHPC) in the United States through 2020. UHPC connections between prestressed concrete voided slabs are the subject of the Concrete Bridge Technology article on page 33, and UHPC link slabs are discussed in the FHWA article on page 58.

https://asbi-assoc.org/learn/webinars
The Safety and Serviceability article on page 40 discusses wind loads on structures and is based on information presented in August 2023 during one of the American Segmental Bridge Institute's (ASBI's) monthly webinars. Recordings for this webinar and other ASBI webinars can be accessed via this link.

https://asbi-assoc.org/industry-wide-videos
The article on page 36 spotlights ASBI as part of a series on National Concrete Bridge Council members. ASBI's mission is to advance, promote, and innovate concrete segmental bridge technology; share the knowledge; educate stakeholders; build professional relationships; and increase the value of our infrastructure by providing sustainable solutions. This is a link to videos on concrete segmental projects and technology available on ASBI's website.

https://abc-utc.fiu.edu/mc-events/new-mexicos-precast-uhpc-abc-bridge-nm-50-over-glorieta-creek/?mc_id=754
New Mexico is featured in the State article on page 44. New Mexico's most recent precast concrete bridge with UHPC closures, NM 50 over Glorieta Creek, was recognized with the 2023 PCI Design Award for All-Precast Concrete Solution and an honorable mention for Bridge with a Main Span under 75 ft. This is a link to a webinar presentation on NM 50 over Glorieta Creek.

http://pci.org/workforce
The recruitment, retention, and wellness of the concrete bridge industry's workforce is paramount, as mentioned in the Editorial on page 2. Toward that goal, PCI has launched a website with tools—videos, resources, and strategies—for workforce development. This is a link to that website.

PCI Offers New Transportation eLearning Modules

Courses on Design and Fabrication of Precast, Prestressed Concrete Bridge Beams

The PCI eLearning Center is offering a new set of courses that will help experienced bridge designers become more proficient with advanced design methods for precast, prestressed concrete flexural members. There is no cost to enroll in and complete any of these new bridge courses.

The courses are based on the content of AASHTO LRFD and PCI publications. These include several State-of-the-Art and Recommended Practice publications, as well as the *PCI Bridge Design Manual*. These are available for free to course participants after registering with a valid email. While the courses are designed for an engineer with five or more years of experience, a less experienced engineer will find the content very helpful for understanding concepts and methodologies.

Where applicable, the material is presented as part of a "real world" example of a complete superstructure design so that students can see how actual calculations are completed according to the AASHTO LRFD specifications.

All courses on the PCI eLearning Center are completely FREE. **Go to: http://elearning.pci.org/**

PCI eLearning Precast, Prestressed Concrete Bridge Girder Series

- **Preliminary Precast, Prestressed Concrete Design** (T110)
- **Materials and Manufacturing of Precast, Prestressed Concrete** (T115)
- **Design Loads and Load Distribution** (T120)
- **Flexure Service** (T125)
- **Flexure Strength** (T130)
- **Prestressed Losses** (T135)
- **Shear** (T145)
- **End Zone Design** (T160)
- **Extending Spans** (T310)
- **Bearing Pads** (T450) and (T455)
- **In-Service Analysis Load Rating** (T710)

Full-Depth Precast Concrete Deck Panels Series

- **Introduction on Full-Depth Panel Precast Concrete Deck System and Its Advantages** (T210)
- **Design and Detailing of Full-Depth Precast Concrete Deck Panels** (T215)
- **Production and Construction Details of Full-Depth Precast Concrete Deck Panels** (T220)
- **Case Studies and Emerging Developments of Full-Depth Precast Concrete Deck Panels** (T225)

Lateral Stability of Precast, Prestressed Concrete Bridge Girders Series

- **Introductory Material and Hanging Girders** (T520)
- **Stability of Transported Girders** (T523)
- **Seated Girders and Stability Issues from Bed to Bridge** (T525)
- **Stability Calculations and Sensitivity Analysis** (T527)

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UHPC Link Slabs: A Simple Solution to Retrofit Bridges to Eliminate Joints

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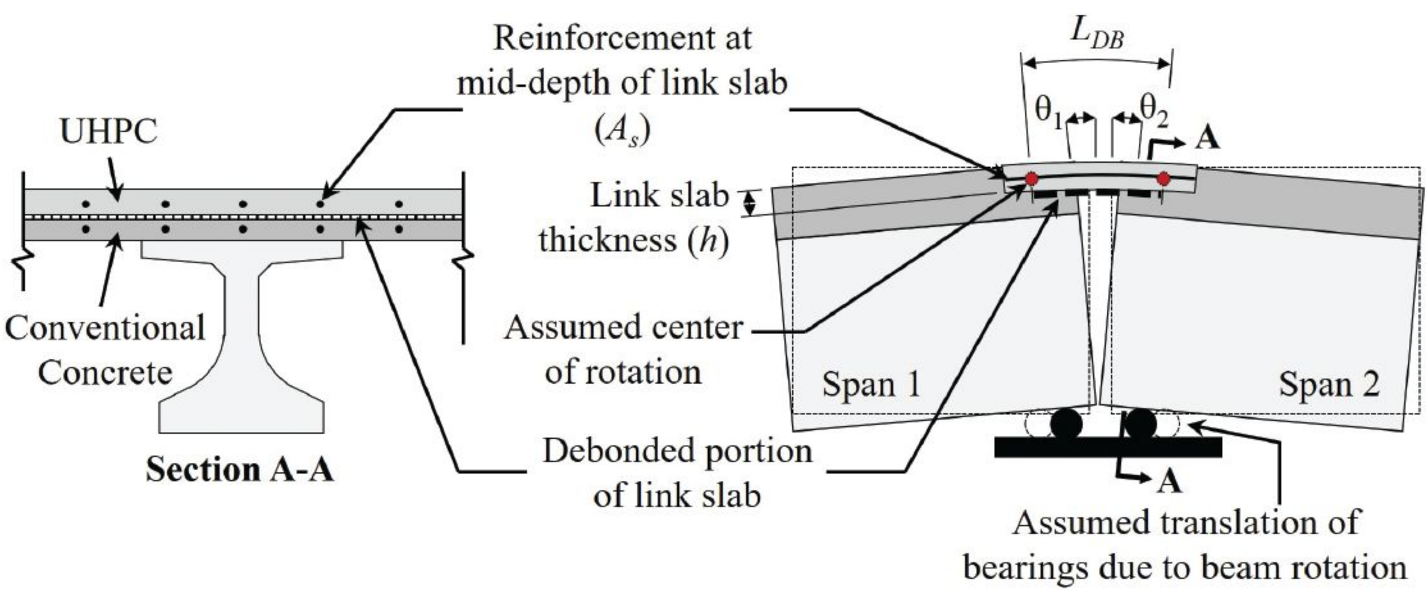
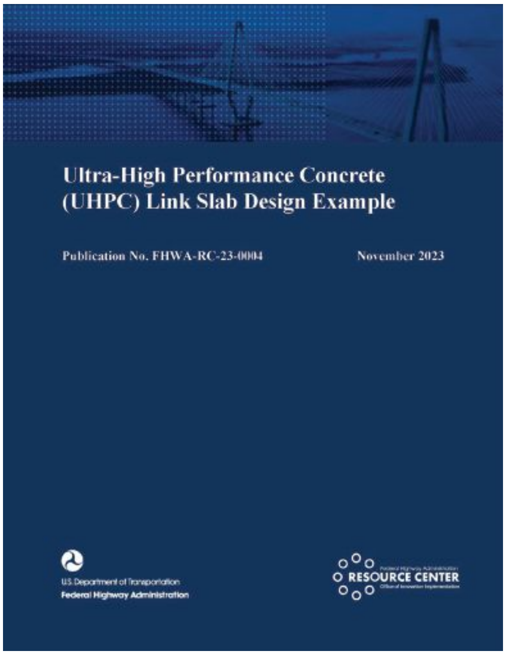
When compared with conventional concrete, ultra-high-performance concrete (UHPC) offers enhanced mechanical and durability properties that make it an ideal material for use in the construction, repair, and preservation of highway bridges. Early widespread adoption of UHPC began with connections between prefabricated concrete bridge elements. UHPC has a high bond strength with conventional concrete substrates and high tensile strength, resulting in shortened development and splice lengths, which makes it an ideal material for connections. The next phase of more widespread adoption of UHPC has involved preservation and repair activities, and has been supported through the Federal Highway Administration (FHWA) Every Day Counts program. UHPC link slabs were identified as one of the most promising applications of UHPC for preservation and repair.[1]

A link slab creates a continuous slab in the longitudinal direction by using a partial- or full-depth slab running between adjacent simple spans that is designed to accommodate the end rotation of the girders without introducing moment continuity between spans. Link slabs can be used to eliminate deck joints between simple spans to help extend the service life of existing bridges. The high tensile strength and post-cracking strain capacity, high bond strength, and decreased splice lengths for embedded reinforcement make UHPC an ideal material for link slabs. UHPC link slabs are typically designed to be only partial depth, often 4 in. deep, and only a few feet long.

Link-slab design is different than the design of conventional reinforced concrete elements, where an element is designed to resist applied loads. The demand on a link slab is generated from the total girder end rotations from the ad-

Figure 1. Typical ultra-high-performance concrete link-slab configuration for retrofitting a precast concrete beam bridge with a composite cast-in-place deck superstructure to eliminate deck joints. All Figures: Federal Highway Administration.





jacent spans occurring after link slab installation: $\theta_T = \theta_1 + \theta_2$ for a configuration like that shown in **Fig. 1**, where θ_1 is the girder end rotation from span 1, and θ_2 is the girder end rotation from span 2. The primary design assumption for UHPC link slabs is that the center of rotation at the end of the girder moves from the top of the bearing, before installation of the link slab, to the centroid of the UHPC link slab, after installation of the link slab (Fig. 1). This assumption allows for the link slab to be designed for only rotation, not axial demand (other than thermal effects and shrinkage). Link slabs are debonded from the girders or composite deck to allow the demand from end rotations to be evenly distributed over the debonded length of the link slab. This results in an average curvature over the debonded length of the link slab ψ_{avg} that is equal to the total rotation from both spans θ_T divided by the debonded length L_{DB}: $\psi_{avg} = \theta_T/L_{DB}$.

The link-slab thickness h, debonded length L_{DB}, and longitudinal reinforcement A_s are designed to resist this "applied" average curvature ψ_{avg}. Service I, Fatigue I, and Strength I limit states are checked in the design process, including the effects of shrinkage and thermal deformations. The bearings must be designed for the additional translation caused by the shift in the center of end rotation (Fig. 1). The substructure must be designed for additional horizontal forces caused by the connectivity across the superstructure created by the installation of the link slabs at any supports or bearing types that can transfer horizontal forces to the substructure.

A recent FHWA report, *Ultra-High Performance Concrete (UHPC) Link Slab Design Example*, presents a design example for a UHPC link slab.[2] The example illustrates the step-by-step process of designing link slabs to replace the expansion joints on a four-span superstructure. The example is for a steel simple-span composite bridge containing traditional expansion joints, but the same design principles and process would be applicable to a prestressed concrete simple-span composite bridge. Construction details are provided for the existing structure and link-slab design. Calculations are provided to determine the longitudinal horizontal loads for the structure to evaluate the effect of the link slabs on the existing substructure and foundation elements. The redesign of the bearings is also included, and the procedure for accounting for thermal effects and shrinkage in the link-slab design is provided. Additional details on previously constructed link slabs and the approaches used by several states for the design and implementation of link slabs are summarized by Thorkildsen[3] and Ailaney.[4]

The FHWA link-slab design example is a valuable resource to bridge owners and bridge designers looking for a simple and innovative solution to retrofit deteriorated or leaking bridge deck joints and preserve the superstructure and substructure elements below them.

References

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