ASPIRE®

THE CONCRETE BRIDGE MAGAZINE

FALL 2022

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A Scientific Approach to Engineering Problem-Solving

WJE melds structural evaluation with forensic investigation

FIVE REPLACEMENT STRUCTURES
Amarillo District, Texas

SOUTHWEST LIGHT RAIL TRANSIT PROJECT: EXCELSIOR BOULEVARD BRIDGE
Hopkins, Minnesota

RODANTHE "JUG HANDLE" BRIDGE
Dare County, North Carolina

Presorted Standard
Postage Paid
Lebanon Junction, KY
Permit No. 567

Photo: Texas Department of Transportation.

Photo: AECOM.

Photo: RK&K

CONTENTS

Features

Departments

Photos: AECOM.

Advertisers' Index

EDITORIAL


Photo: PCI.

Stupid Choices Can Be Painfully Expensive

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

I mentioned the shortage of labor and its impact on our industry in my last editorial. The problem is a bit more complicated than just a lack of folks in the resource pool. We are definitely experiencing a personnel shortages. Whether caused by the "great resignation," retirements, transforming professional opportunities, or our community not creating some positive excitement, this deficit of human capital is significant. Given our inherent technical and professional obligations, and the educational rigors of our discipline, there is no silver bullet to rapidly reverse this trend. Recognition is the first step in addressing this concern, and Dr. Brandon Ross from Clemson University shares some valuable feedback in the Professor's Perspective article on page 59.

I remember quite vividly from earlier in my career, in both government and the private sector, the challenges of cultivating, educating, and developing a competent engineering workforce. I often thought, "How can I send a valued member of my design squad away for training for a period of time when we have projects to deliver?" I have always believed, and continue to believe, that by providing an opportunity to advance an employee's knowledge and skill, the team as a whole reaps the benefits. I knew one supervisor who kept telling his leadership, "We do not have time for a week-long training of an employee who will leave us in two years." The best response I ever heard was, "Okay, just remember: stupid choices can be painfully expensive, and then what are you going to tell me when they have stayed here for 10 years?" We must invest time and resources to help everyone grow their expertise so they can make greater contributions to our organizations.

The Summer 2022 issue of *ASPIRE*® contained two articles highlighting exciting programs designed to increase the level of understanding and advance engineering expertise. The Concrete Bridge Engineering Institute (CBEI) and Caltrans Bridge Design Academy are both great examples of programs aimed directly at strengthening the knowledge base of our workforce. CBEI's initial three pillars of learning, based on collaborative input from state, federal, and industry experts, are Concrete Materials, Bridge Deck Construction Inspection, and Post-Tensioning. These three areas represent some of the most immediate needs for knowledge development in our industry. The Caltrans Bridge Design Academy, which traces its lineage back to the 1960s, is a dynamic program aimed at employee development on a range of technical topics. Of note, completion of several PCI eLearning classes is now a prerequisite for admission into the Caltrans program. The eLearning courseware is an example of industry-developed online resources made available to everyone, at no cost, to help practitioners gain critical knowledge in an efficient and cost-effective manner. The challenge to the broader community is to create internal programs for developing your team by leveraging industry and institutional (federal, state, and academic) resources. Collaboration is key; don't re-create what already exists.

I'm pleased to announce that going forward, *ASPIRE* will include a recurring CBEI column (see page 53). This is an exciting time in our profession, and this series will keep us connected and up to date on the many developments at CBEI. It is also appropriate to recognize the collaborative effort underway between the National Concrete Bridge Council (NCBC) and the American Association of State Highway and Transportation Officials (AASHTO) that is outlined in the Perspective article about NCBC on page 14. Expect to see, in the very near future, published industry resources that are cobranded by AASHTO and NCBC. These resources will provide opportunities for continued growth of knowledge for industry practitioners.

While collaboration is a necessity for our industry, we must also continue to innovate and leverage technologies and the sciences to our advantage. The saying "good science should lead to good policy" is just that, a saying, with an emphasis on the word *should*. Emily Lorenz writes in a Perspective article on

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American Segmental Bridge Institute

Epoxy Interest Group

Expanded Shale, Clay and Slate Institute

NRMCA National Ready Mixed Concrete Association

PCI Precast/Prestressed Concrete Institute

Post-Tensioning Institute

SFA Silica Fume Association

the background of sustainability and the movements toward a longer-term viewpoint (page 30). My takeaway from her article is that it is essential to work with good science and not overgeneralize tenets that are easily misused; to that end, *ASPIRE* and NCBC will continue to bring you both data and perspectives on those data. Dr. Timothy Wyatt's Perspective article on Buy America requirements illustrates the very real challenges our industry faces when policy meets construction procurement.

During the general session of the annual business meeting of the AASHTO Committee on Bridges and Structures, the full committee noted many retirements and changes in membership. Despite the turnover, the AASHTO T-10 technical committee on concrete design is well positioned to assist policy makers with ideas and language to better connect and inform our industry. Industry participation is also a critical component in T-10's success. The goal is always to meet the needs of our end users through sound policy grounded in unparalleled engineering.

In future issues, we will highlight Concrete Bridge Stewardship programs and concepts launched through a six-part webinar series hosted by NCBC, focusing on better evaluation tools, immersive learning goals, concrete repair techniques and practices, design solutions, strengthening bridges, and long-term bridge protections. These webinars will soon be available on the NCBC website (https://nationalconcretebridge.org) for those who missed them the first time or would like to watch them again.

Additionally, I continue to read your input via email: info@aspirebridge.org. Knowing what resonates with readers, and what does not, is of tremendous value to our team at *ASPIRE*. Thank you for your continued support.

Lastly, I want to personally thank managing technical editor Dr. Reid Castrodale for his efforts in keeping the *ASPIRE* team on track during these past eight years and congratulate him on moving to emeritus status. Over the years we have focused our combined efforts on three areas: career growth, technical advancements, and ethics and professionalism. Thank you, Reid, and best wishes to you and your family!

EDITOR'S NOTE

The Federal Highway Administration has announced that an update to 23 CFR part 650 Subpart C, National Bridge Inspection Standards (NBIS), was published on May 6, 2022. As part of that update, the incorporated reference for the reporting of highway bridge data to FHWA for inclusion in the National Bridge Inventory is now the Specifications for the National Bridge Inventory *(SNBI) which replaces the* Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges *(Coding Guide) and the* Specifications for the National Bridge Inventory Bridge Elements *(SNBIBE). The new SNBI, a memo on implementation of the SNBI, and a data crosswalk between the new SNBI data items and the previously used Coding Guide and the SNBIBE data items, can be downloaded at this link: https://www.fhwa.dot.gov/bridge/snbi.cfm*

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CONCRETE CALENDAR 2022–2024

The events, dates, and locations listed were accurate at the time of publication but may change as local guidelines for gatherings continue to evolve. Please check the website of the sponsoring organization.

October 4–7, 2022
PTI Committee Days
JW Marriott Cancun Resort & Spa
Cancun, Mexico

October 23–27, 2022
ACI Fall 2022 Convention
Hyatt Regency Dallas
Dallas, Tex.

October 31, 2022
Submission Deadline for 2023 PTI Project Awards
https://www.post-tensioning.org/events/awards/ptiprojectaward

October 31–November 2, 2022
ASBI 2022 Annual Convention and Committee Meetings
Hyatt Regency
Austin, Tex.

November 6–12, 2022
PTI Certification Training: All Levels
Sheraton Austin Hotel at the Capitol
Austin, Tex.

December 7–9, 2022
2022 International ABC Conference
Hyatt Regency Miami
Miami, Fla.

January 8–12, 2023
Transportation Research Board Annual Meeting
Walter E. Washington Convention Center
Washington, D.C.

January 16–19, 2023
World of Concrete
Las Vegas Convention Center
Las Vegas, Nev.

February 21–25, 2023
PCI Convention at The Precast Show
Hyatt Regency & Greater Columbus Convention Center
Columbus, Ohio

April 2–6, 2023
ACI Spring 2023 Convention
Hilton San Francisco Union Square
San Francisco, Calif.

April 28–May 4, 2023
PTI Convention
JW Marriott Marquis Miami
Miami, Fla.

May 21–25, 2023
AASHTO Committee on Bridges and Structures Annual Meeting
Kansas City, Mo.

June 12–14, 2023
International Bridge Conference
Gaylord National Resort & Convention Center
National Harbor, Md.

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

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

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

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

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

September 23–27, 2024
PCI Committee Days Conference
Loews Chicago O'Hare
Chicago, Ill.


Question today
Imagine tomorrow
Create for the future
J.T. Brooks Bridge replacement, Okaloosa County, Florida

FOCUS

A Scientific Approach to Engineering Problem-Solving

Wiss, Janney, Elstner Associates' structural evaluations and forensic investigations make significant contributions to the construction industry

by Monica Schultes

From its humble beginnings as a one-man firm in 1956, Wiss, Janney, Elstner Associates (WJE) has become synonymous with problem-solving and investigative work. The company's engineers, architects, and materials scientists are involved in an ever-widening array of services aimed at solving problems in the built world. "Effective use of field and laboratory testing is in our DNA," says Gary Klein, executive vice president and senior principal with WJE.

Jack Janney, WJE's founder, coined the expression "ask the structure," which harkens back to his research background with the Portland Cement Association. "Our investigators rely on testing, experimentation, and instrumentation to better understand the problem—the most important step in solving it," says Klein. "The firm's success is founded on delivering better solutions, starting with asking the structure."

For example, when the Chicago Department of Transportation asked WJE to confirm that the planned replacement of the Wacker Drive Viaduct would last 100 years, the WJE team followed Janney's directive. Based on findings of an earlier WJE investigation, the team concluded that the badly deteriorated main thoroughfare needed to be rebuilt using high-performance concrete. In addition to developing and testing concrete mixture proportions for improved durability, a full-size prototype of a portion of the structure was developed to test its structural response. WJE was subsequently hired to develop long-term health monitoring for the viaduct.

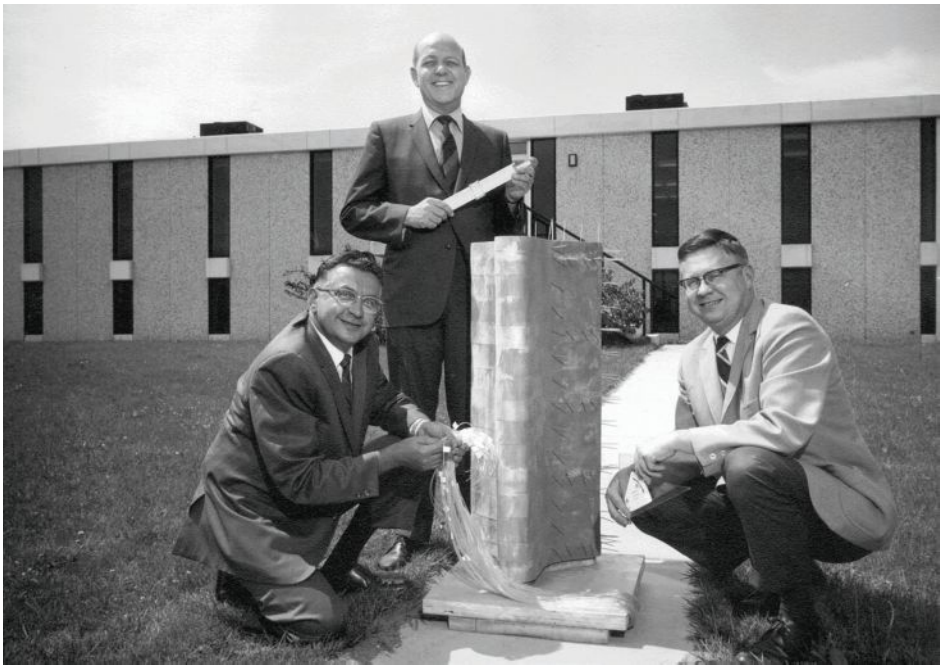
"Our investigators rely on testing, experimentation, and instrumentation to better understand the problem …The firm's success is founded on delivering better solutions, starting with asking the structure."

Attracting Outstanding Talent

Challenging work and complex problem solving appeal to the talented engineers, architects, and materials scientists (most with advanced degrees) who join WJE. Their sharp minds want to be a part of solving built-world mysteries.

Michael Lee, principal with WJE, recalls that he was attracted to the firm for two reasons: the in-house materials sciences resources (such as petrography and chemistry) and the firm's Janney Technical Center (JTC) laboratory in Northbrook, Ill. Those assets give WJE the ability to supplement engineering theory and numerical modeling. "All firms can use software to run the numbers, but to really understand the structure, having the complete package of technical resources often makes the difference. Those professionals who want

Wiss, Janney, Elstner Associates conducted field investigations of the Central Artery Tunnel (Big Dig) project in Boston, Mass. This involved visual inspections and nondestructive testing that included sounding the bearing area near epoxy-injected cracks on the Zakim Bridge. Photo: Metropolitan Highway System.



Left to right, founding partners and pioneers Jack Wiss, Jack Janney, and Dick Elstner. The firm that bears their names has become synonymous with forensic investigations, testing, and cutting-edge research. Photo: Wiss, Janney, Elstner Associates.

to dig a little deeper into the nuances of structural and materials behavior find a home at WJE," explains Lee.

WJE nurtures a cross-disciplinary exchange of ideas. Technical resource groups meet routinely, and discussion forums are in place to query experts throughout the company. Information from investigations is shared across teams through webinars, white papers, and workshops.

"Collectively, our employees and the knowledge that we have learned over 65-plus years is our largest and most valuable asset," says Andrew Osborn, senior principal at WJE. "Most of our work product is written reports, which are found in a searchable database," he adds. "We help our associates develop and grow professionally through mentoring, but we place a high degree of responsibility on individual initiative. It is a two-way street, not just top-down instruction," he says.

Extensive In-House Facilities

In 1967, WJE's founders built a structural laboratory at the Northbrook, Ill., headquarters. In 1985, WJE added concrete chemistry and petrographic expertise with the acquisition of Erlin Hime Associates. The company consolidated its laboratories in a new building on the Northbrook campus five years ago.

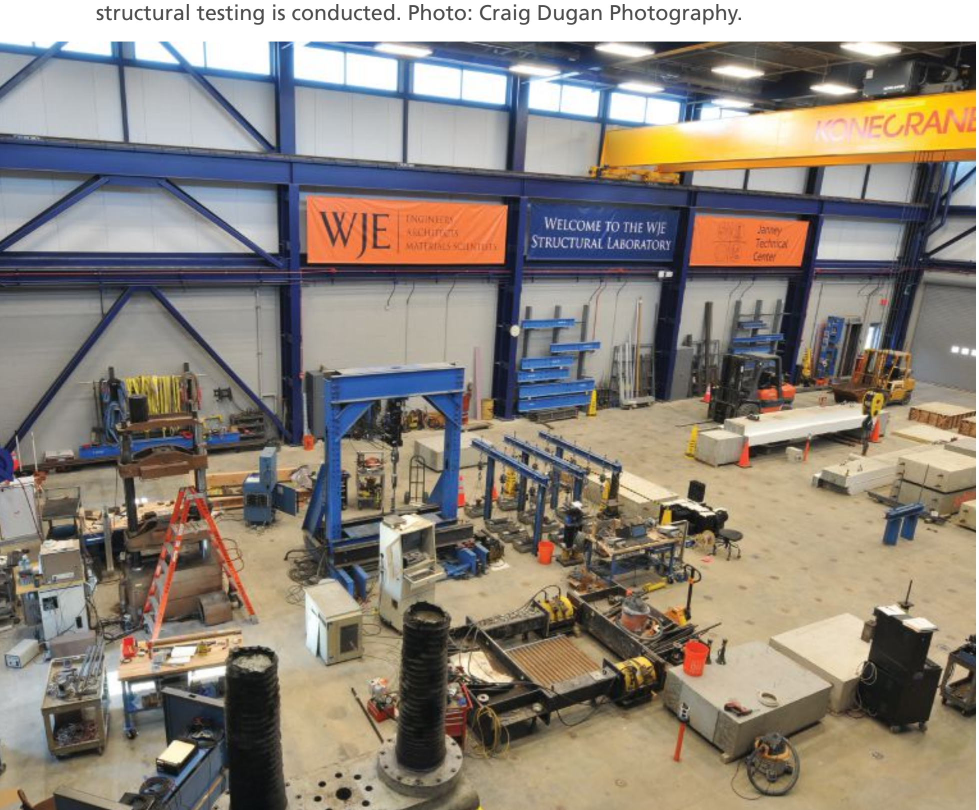
JTC is a state-of-the-art, 70,000 ft^2 testing and applied research facility that includes a full array of chemistry, petrography, metallurgy, concrete and mortar, corrosion, and structural testing laboratories, as well as environmental exposure chambers, for hands-on problem solving. JTC also includes space for large-scale structural testing of everything from wall samples to bridge retrofits. Other laboratories in Austin, Tex., and Cleveland, Ohio, supplement the main facility.

In addition to its broad array of structural engineering, architecture, and building envelope services, WJE offers fire protection, geotechnical engineering, metallurgy, applied mechanics, and movable bridge engineering services. The firm is therefore uniquely positioned with its in-house field-testing abilities and laboratory support. Osborn describes the importance of WJE's internal testing capabilities as "vital to our business."

Professional Contributions

WJE believes in doing the right thing, especially with lessons learned in the aftermath of a tragedy. WJE team members share findings through their participation in professional associations, webinars, white papers, presentations, and articles. Each year, technical staff from WJE author nearly 100 published papers and present more than 300 talks at professional conferences or meetings. In addition, the firm's employees contribute to the advancement of their professions by serving in leadership positions at PCI, the American Concrete Institute, the American Society of Civil Engineers, ASTM International, and other technical organizations and committees.

Wiss, Janney, Elstner Associates has its own in-house testing facilities and laboratories. The firm's main research facility is the state-of-the-art, 70,000 ft^2 Janney Technical Center, where chemistry, petrography, metallurgy, concrete, corrosion, and large-scale structural testing is conducted. Photo: Craig Dugan Photography.



WJE has conducted many research projects on behalf of PCI and others regarding concrete curing temperatures, interface shear, strand bond, ledger-beam behavior, headed stud anchors, dapped-end double-tee beams, and, most recently, ultra-high-performance concrete (UHPC). "These were all important topics to the industry, and we like to think we made contributions with those research projects," says Osborn.

Since grout voids in post-tensioning ducts were identified as a condition that could potentially promote a corrosive environment within post-tensioning (PT) tendons, WJE has been frequently consulted. For example, in Oahu, Hawaii, investigators used ground-penetrating radar to identify tendon ducts with potential voids. The voids were detected with MIRA ultrasonic tomography, and grout samples were collected for further laboratory studies. No tendon corrosion was found, and the use of nondestructive testing methods helped develop a work plan for future inspection of the pre-2003 PT bridge inventory.

On the materials side, WJE recently collaborated with PCI, e.construct USA, the University of Nebraska-Lincoln, North Carolina State University, and Louisiana Tech University on the advancement of nonproprietary UHPC. "We have to stay ahead of other competing materials,

Jack Janney, Special Investigator

Jack Janney founded the one-person engineering firm Janney and Associates in 1956. More than 60 years later, Wiss, Janney, Elstner Associates (WJE) has evolved into a prominent company that has been involved in investigating and mitigating some of the world's most challenging construction-related problems.

Janney had worked at the Portland Cement Association (PCA) before venturing out on his own. At first, his firm provided regular design services as well as testing and investigation services, but the partners gravitated to the latter. Janney's neighbor, John (Jack) Wiss, an expert in sound and vibration, joined Janney in 1957. In 1962, Richard (Dick) Elstner, also from PCA, joined them to form WJE in Northbrook, Ill., just north of Chicago. Janney and his partners quickly earned a worldwide reputation and became industry titans.

Over his career, Janney investigated at least 500 major structural collapses and more than 4000 cases of suspected structural distress. When he wasn't conducting research or supervising investigations, he pioneered the use of three-dimensional structure models as design aids before the use of computer software.

In the early years, the firm investigated significant events such as the Silver Bridge collapse over the Ohio River, the MGM Grand Hotel fire in Las Vegas, Nev., the Hyatt Regency Hotel walkway failure in Kansas City, Mo., and the Cline Avenue Overpass Collapse in East Chicago, Ind. Janney was also instrumental in the early use and testing of prestressed concrete beam bridges along the Illinois Tollway in the 1960s.

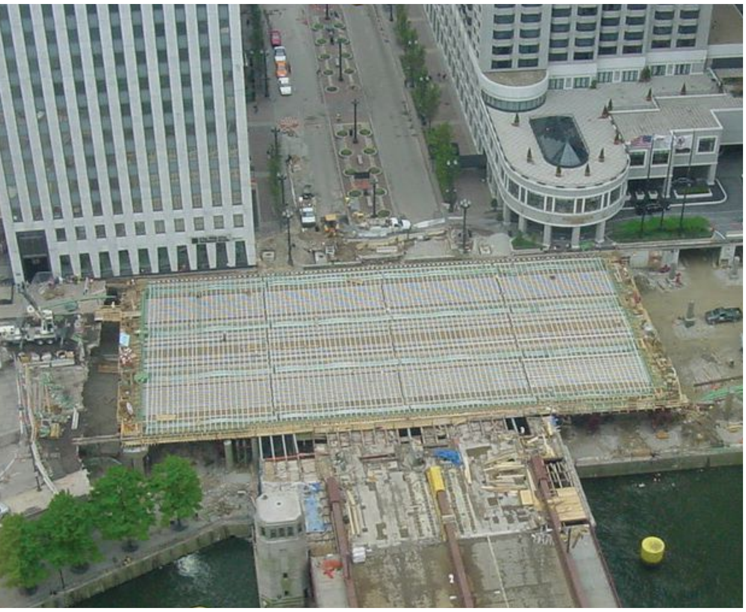
Janney was involved in professional organizations such as the American Society of Civil Engineers (ASCE), the American Concrete Institute, the American Society for Testing and Materials (now ASTM International), and PCI.

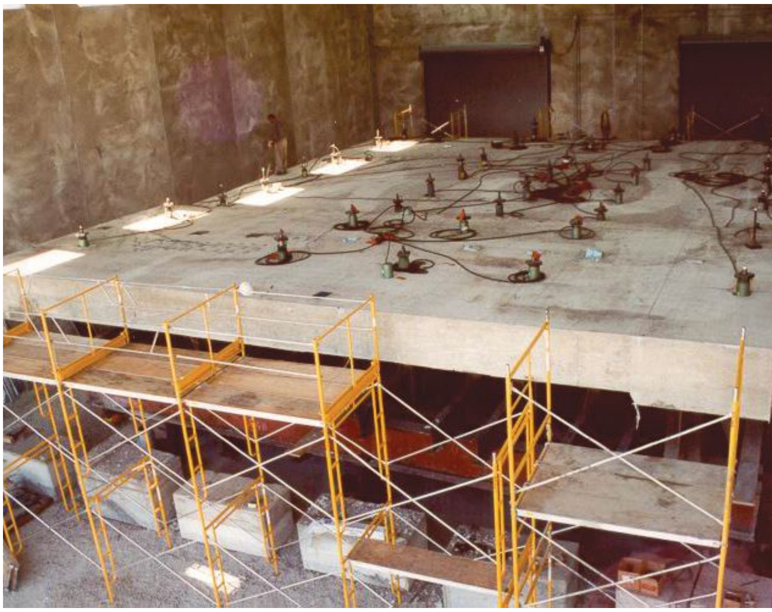
He even found time to write. In the 1950s, he authored the first edition of PCI MNL 115, *Fundamentals of Prestressed Concrete Design*. In the 1970s, he wrote an ASCE textbook titled *Guide to Investigation of Structural Failures*, and various articles for ASCE Special Technical Publications.

Janney was instrumental in the formation of the Architects and Engineers Insurance Company in the late 1980s, which offered professionals errors and omissions insurance, and he was an advocate for dispute resolution procedures to resolve construction and engineering issues.

Janney received numerous professional honors throughout his career, including being named one of *Engineering News-Record's* top 20 structural engineers of the last 125 years.

The Chicago Department of Transportation asked Wiss Janney Elstner Associates (WJE) to confirm that the planned replacement of the Wacker Drive Viaduct (shown under construction on the left) would last 100 years. To achieve that goal with relative certainty, WJE developed and tested concrete mixture proportions for improved durability and built a full-size prototype of a portion of the upper deck of the structure (right) to test structural response. Photos: WJE.





and through the UHPC project, we like to think we are contributing to those advances," says Osborn.

Corrosion Assessment Software

"Deterioration of concrete bridges is all driven by exposure to water," explains Osborn. "We have done extensive research on sealants, cathodic protection, and other solutions used to protect areas that are vulnerable to corrosion."

WJE developed Corrosion Assessment and Service Life Evaluation (WJE CASLE) software to predict corrosion-related damage in concrete structures. Using models generated from decades of data from testing corrosion damage in concrete structures, coupled with the firm's extensive knowledge and work on durability and minimizing corrosion, CASLE software predicts the probability that a structure will last a certain number of years. The input parameters include items such as stainless steel and epoxy-coated reinforcing bars and sealants, which typically contribute to a longer service life. The corrosion assessment conducted using this tool can assist with decisions on asset management.

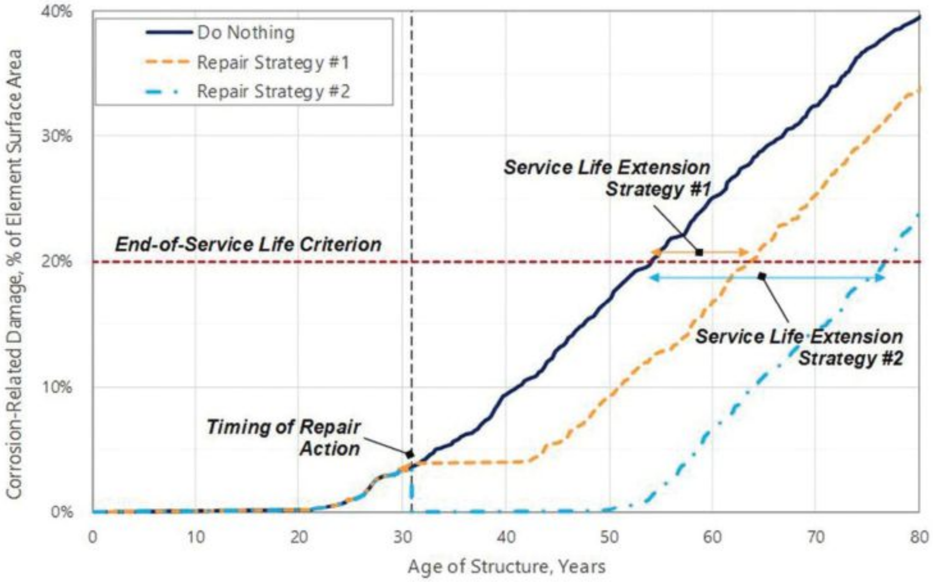
Solving for Why

WJE has been called upon to examine many major structural collapses in the United States. "Our work is somewhat like that of a forensic pathologist, but for the built world," observes Osborn. "We uncover lessons that can help society prevent similar occurrences in the future."

"Our work is somewhat like that of a forensic pathologist, but for the built world. We uncover lessons that can help society prevent similar occurrences in the future."

When tunnel ceiling panels fell several years after construction was completed in a section of the Big Dig in Boston, Mass., WJE completed a "stem-to-stern safety audit" in 90 days. Klein recalls that the challenge was to prioritize what areas and components were most vulnerable to deterioration and failure. The ability to distinguish between what was in good shape and which areas needed attention was critical.

Wiss, Janney, Elstner Associates developed Corrosion Assessment and Service Life Evaluation (WJE CASLE) software to predict service life of concrete structures. This WJE CASLE–generated plot compares alternate repair strategies: Strategy 1 slows the progression of corrosion-related damage, whereas Strategy 2 repairs existing damage and removes the cause of the deterioration (for example, chloride-contaminated concrete). Comparisons such as this can be used to evaluate the costs and benefits of different repair strategies. Figure: WJE.



Clients seek WJE expertise when there is no obvious cause for a failure. Many collapses happen during construction or demolition, when there is increased instability. "One of the advantages in this business is 20-20 hindsight," says Osborn. "In these cases, we are able to conduct our investigation after the fact instead of trying to anticipate what could go wrong," he concludes.

The firm is involved in resolving insurance and litigation disputes, and employees frequently serve as expert witnesses. Osborn's work with insurance companies began with the bombing of the World Trade Center in 1993 and has grown to the point where almost half of the work he does deals with insurance and litigation.

While WJE will continue to be involved in promoting a better understanding of past performance, the firm is also experiencing a shift toward prevention as an industry priority. Requests for peer reviews are on the rise as clients consult with WJE as a proactive measure.

Infrastructure Solutions

Bridges are subjected to harsh conditions and require maintenance for improved long-term performance. By investigating thousands of bridges and bridge failures, WJE engineers have learned that with better understanding of potential problems comes better design and construction techniques.

Using the latest technology, such as three-dimensional imaging, WJE bridge engineers are able to re-create or reassemble the aftermath of a collapse to determine the root cause. "We still rely on tried-and-true methods like pulse velocity and impact echo. Having all these capabilities in house makes a huge difference for us," says Klein.

WJE's diverse and extensive expertise allows the firm to consistently deliver practical solutions. "We offer insights to those designing and building our infrastructure," says Klein. "This firm got its start with concrete bridges and after almost seven decades, it is still the heart and soul of what we do and what we are all about."

Update to the Buy America Requirements for Highway Bridge Projects

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

The Infrastructure Investment and Jobs Act (IIJA) enacted on November 15, 2021, contains a new Buy America requirement that "none of the funds made available for a Federal financial assistance program for infrastructure … may be obligated for a project unless all of the iron, steel, manufactured products, and construction materials used in the project are produced in the United States."

At first glance, this appears similar to existing Buy America requirements for U.S. Department of Transportation (USDOT) agencies. Under the Federal Highway Administration (FHWA) Buy America provision codified at 23 U.S.C. §313, all iron, steel, and manufactured products used on federally assisted highway projects are to be manufactured in the United States, with FHWA authorized to issue waivers under certain circumstances (see the article in the Fall 2020 issue of *ASPIRE*®). However, in 1983, FHWA issued a permanent waiver for manufactured products, so the FHWA Buy America provision has almost always applied only to steel and iron. FHWA also issued regulations permitting a *de minimis* amount of nondomestic steel or iron, not to exceed 0.1% of the total contract price.

The main substantive change with the IIJA is the inclusion of "construction materials" as a new category of product subject to Buy America requirements. In guidance issued by the White House Office of Management and Budget (OMB) on April 18, 2022, under its authority under the IIJA, construction materials include products consisting "primarily" of nonferrous metals, plastic and polymer-based products, glass, lumber, and drywall. The OMB expressly excluded other manufactured products, predominantly steel or iron products, and certain paving materials (aggregate, cement, and binding agents) from the definition of construction materials. The new IIJA Buy America provision requires that "all manufacturing processes" for construction materials take place in the United States. FHWA has strictly enforced similar language for steel and iron under the FHWA Buy America provision. IIJA does not provide for a *de minimis* amount of nondomestic construction materials to be used on a project.

Most products falling under the new definition of construction materials were previously treated as manufactured products under the FHWA Buy America provision, and were thus exempt from Buy America requirements due to FHWA's manufactured products waiver. For example, in a November 1980 *Federal Register* notice previewing the manufactured products waiver, FHWA asserted that state highway agencies "urged caution" in imposing Buy America requirements on products such as aluminum and plastic.

With the manufactured products waiver in place, the main Buy America issue for FHWA in recent years has been the treatment of manufactured products that contain iron and steel components, including screws, bolts, nuts, and washers, for which it can be difficult, if not impossible, to determine the country of origin. FHWA has attempted to distinguish between predominantly steel and iron products, which are subject to Buy America requirements, and commercial off-the-shelf (COTS) products that contain iron and steel components, which would be eligible for the manufactured products waiver. However, as discussed in the Fall 2020 issue of *ASPIRE*, FHWA's guidance distinguishing between those two categories has been largely withdrawn due to an adverse court ruling in 2015 and public opposition to rulemaking efforts in 2016. Since then, it has been largely left to the discretion of individual FHWA divisions to determine whether a given COTS product is predominantly steel or iron, and thus subject to Buy America requirements.

The April 18, 2022, OMB guidance provides that products may not be classified in more than one category: steel or iron product, manufactured product, or construction material. The IIJA further provides that its new Buy America provision only applies to the extent that there is not an existing Buy America requirement in place covering those three categories. Because the existing FHWA Buy America provision nominally applies to iron, steel, and manufactured products (even though FHWA has waived coverage for manufactured products), the new IIJA Buy America requirements arguably apply only to construction materials on FHWA projects.

The new IIJA Buy America requirements were to be effective within 180 days of enactment, which would have been May 14, 2022. However, on April 28, 2022, USDOT proposed a temporary waiver for construction materials, delaying implementation for 180 days, due to uncertainty regarding how the proposed extension of Buy America requirements to construction materials would impact FHWA projects. With regard to bridges, USDOT stated in support of the temporary waiver, "there are more than 62,588 bridges with wood or timber elements (including 16,909 bridges whose main span have wood or timber elements), 2,281 bridges with non-ferrous metal elements, and 19,562 bridges with polymer-based products elements." USDOT requested public comment on the proposed temporary waiver for construction materials.

Comments from groups representing public owners and contractors generally voiced unease about the new Buy America requirements for construction materials. Representing that its members own 38% of the nation's bridges, the National Association of Counties requested a longer waiver period. The American Association of State Highway and Transportation Officials echoed the request for a longer waiver period and also warned that products presently covered by FHWA's manufactured products waiver (such as plastic pipe, glass-fiber reinforcement, and aluminum products) will apparently be subject to Buy America requirements under the new IIJA provision covering construction materials. Similarly, noting that FHWA has long struggled with how to apply Buy America requirements to steel and iron components of COTS products, the American Road & Transportation Builders Association expressed concern that the struggle will intensify once Buy America requirements apply to products composed of aluminum, plastic, and glass, and urged FHWA to adopt a general waiver for COTS products.

However, comments received from manufacturing industry groups and organized labor (including the International Association of Bridge, Structural, Ornamental and Reinforcing Iron Workers) generally voiced support for the new Buy America requirements for construction materials and encouraged robust enforcement with few waivers. The National Steel Bridge Alliance division of the American Institute of Steel Construction asserted that neither the new legislation nor the proposed waiver for construction materials should affect the existing strict FHWA Buy America requirements for iron and steel.

On May 25, 2022, USDOT issued the temporary waiver of Buy America requirements for construction materials. Although the waiver period is nominally only 180 days, it exempts Buy America requirements for construction materials on all awards of USDOT funds that are obligated between May 14, 2022, and November 15, 2022, with the waiver applying for the duration of those awarded projects. Because some of those projects may take years to complete, the construction materials waiver will provide relief for quite some time.

However, absent an extension of the waiver, Buy America requirements will apply to construction materials, including products consisting primarily of lumber, plastic, glass, or aluminum, on projects awarded after November 15, 2022. Where there is no domestic source for a specific product, FHWA can waive the Buy America requirements, using the same procedure by which FHWA has occasionally issued project-specific waivers in recent years for certain predominantly steel or iron products, including reinforcement used in specialty reinforced concrete products.

Although Congress expressly provided in the IIJA that the new Buy America requirements apply to all manufactured products in addition to iron, steel, and construction materials, it is possible that FHWA will maintain that its long-standing manufactured products waiver was not disturbed by the IIJA. That would allow certain COTS products to be used on future FHWA projects without regard to whether those products were manufactured in the United States, even if certain components of those products consist of materials otherwise subject to Buy America requirements (such as steel, iron, aluminum, wood, glass, plastic, or other polymers), as long as the product does not consist primarily or predominantly of such materials. The discretionary authority of FHWA divisions would presumably expand from simply determining whether a given COTS product is predominantly steel or iron to also include determining whether the product consists primarily of construction materials such as nonferrous metal, wood, glass, plastic, or other polymers.

If the construction materials waiver is allowed to expire, products consisting primarily of those construction materials will no longer be exempt from Buy America requirements on FHWA projects under the manufactured products waiver. The long-running controversy over what constitutes predominantly steel and iron products may foreshadow a larger forthcoming dispute over what constitutes products consisting primarily of construction materials. A

EDITOR'S NOTE

We thank Dr. Timothy R. Wyatt, Esquire, who is well versed in matters related to Buy America provisions, for providing this informative follow-up to his initial article on Buy America requirements, which appeared in the Fall 2020 issue of ASPIRE.

DISCover a Tool to Foster Better Communication

by Elaine (Lainey) Lien, ReVive Careers

It is said humans are like snowflakes in that no two are exactly the same. Although humans do share communication style similarities, our distinctive communication styles often create confusion, conflict, and challenges in life and work.

On average, we spend 75% to 80% of our waking hours communicating with others in one fashion or another, for example, verbal, written, body language, or electronic communication. With so many ways of communicating, one would think we should all be experts at this communication thing. If this were true, I would be out of a job! The reality is that poor communication, or a complete lack of communication, happens to be one of the biggest complaints in the workplace.

In my article on psychological safety in the Winter 2022 issue of *ASPIRE®*, I introduced the "BE WELL" tool and discussed how effective communication in the workplace is the key ingredient to building highly effective teams. It is essential to achieving business goals, building relationships, and fostering customer satisfaction. In this article, I share a communication enhancement tool I regularly use with my individual and business clients to foster better communication: the "DISC" assessment.

What Is DISC?

DISC is a simple, practical, and accurate universal language tool that measures human behaviors as they relate to communication. The DISC model of communication behaviors was developed by William Moulton Marston.[1] DISC assessments were designed to help people focus on understanding their own communication styles and then, equally as important, how to enhance communication with others. This awareness of self and others is critical for improving communications across the board and reducing conflict and inefficiencies.

According to the DISC model, there are four basic communication styles: dominance, influence, steadiness, and conscientiousness. Each of us is a combination of all four styles; however, we tend to use one or two of the styles most often. Each DISC style naturally and unconsciously provides us with visible clues in the form of observable behaviors and predictable patterns. These clues give us insight as to which DISC style a person is most likely to be. These behaviors and patterns are referred to as a person's DISC language.

Intentionality is the secret sauce to achieving better outcomes with others. When one learns to consciously observe and identify the four styles, it will become easier to intentionally adapt one's own communication style to the other person's style, thus speaking to that person in their DISC language. With awareness and an ability to adapt, we gain an opportunity for improved communication.

Communication Styles

The following sections provide brief descriptions of the four basic DISC styles, followed by tips for communicating more effectively with each. While reading the descriptions, think about which style is most relatable to you. Think also about common interactions in the workplace. Please keep in mind, there are no good or bad, or right or wrong, DISC styles; organizations need a healthy combination of all the styles to thrive.

Dominant Style

Description: Fast paced, problem solver, task oriented, bottom-line driven, risk taker, results oriented. D-style individuals tend to be direct, blunt, outspoken, commanding, competitive, and confident. They thrive on challenges of self, others, and the status quo. D-types are quick decision makers and big-picture thinkers, and they have a sense of urgency like no other style.

Communication tips: When working with D-style communicators, keep interactions quick and to the point. Focus on solutions, not problems. Stand your ground and be ready with bullet points and hard facts. Provide D-types with options to choose from. Recognize, praise, and reward the D-style communicator for doing a great job!

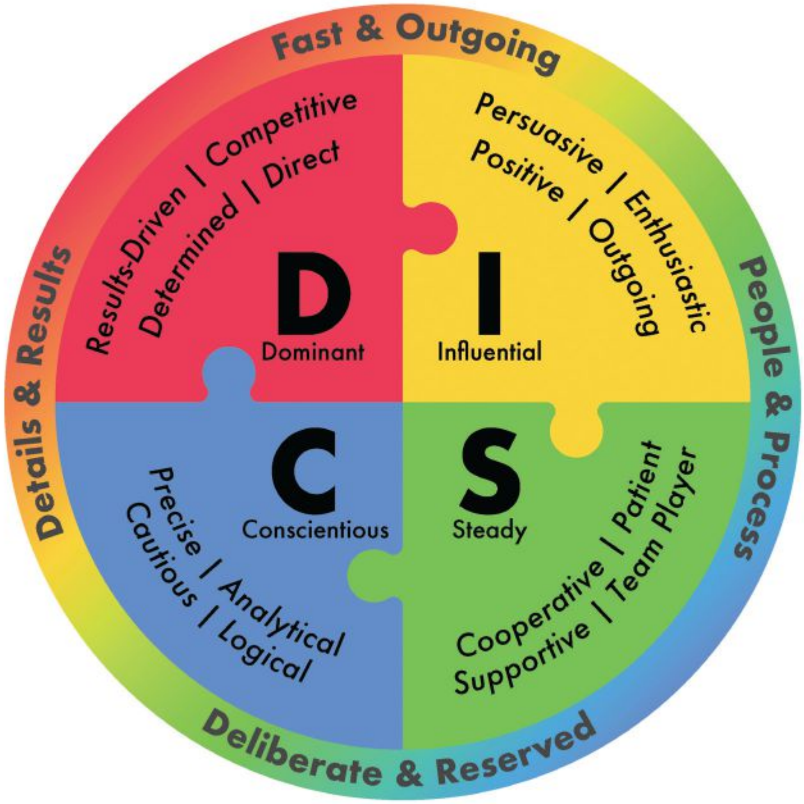
Famous D-style communicator: Simon Cowell

Influential Style

Description: Fast paced, outgoing, persuasive, people oriented, enthusiastic, creative, storyteller. I-style communicators possess an endless supply of positive energy, wit, and charm. I-types love to entertain, rally the troops, and encourage others to take action. They are optimistic, empathetic, and playful. They thrive in team environments and social settings, and they enjoy the spotlight. This style is characteristic of an out-of-the-box-thinker who is also averse to details. I-style communicators dislike confrontation; however, they are naturally gifted mediators and conflict negotiators.

Communication tips: When interacting with I-style individuals, be friendly, upbeat, and allow time for chitchat. I-types tend to have a million ongoing ideas and want to skip the boring details. They appreciate and refer back to emails recapping topics and next steps discussed in recent meetings. Be

DISC Styles



According to the DISC model there are four basic communication styles: dominance, influence, steadiness, and conscientious. Awareness of an individual's communication style, including our own, gives us an opportunity to achieve more effective communication and build relationships. Source: ReVive Careers.

quick to praise I-style communicators and slow to criticize them.

Famous I-style communicator: Robin Williams

Steady Style

Description: Even tempered, moderately paced, people oriented, approachable, friendly, good listener, supportive, relationship oriented. S-style indviduals are quintessential team players, who tend to be cooperative and supportive. They prefer calm and peaceful environments. S-types appreciate rules, routines, and predictability. They dislike change, confrontation, and conflict; however, they tend to champion or crusade for change when it is well directed and benefits the good of others. S-style communicators excel at planning and prefer to take a step-by-step approach to projects.

Communication tips: When working with S-style communicators, be friendly, genuine, and patient. S-style individuals will do more listening than talking, so be sure to ask for their thoughts and clarify key agenda items. S-types prefer one-on-one interactions and step-by-step instructions.

Famous S-style communicator: Princess Diana

Conscientious Style

Description: Moderately paced, task oriented, highly analytical, organized; likes order, structure, and following the rules. C-style communicators have an insatiable need for details, data, and information. They are focused on quality and accuracy. C-style individuals tend to be private and prefer to work alone. C-types do not like change, confrontation, or conflict. They strive for precision and perfection in everything they do, including decision-making.

Communication tips: When working with C-style communicators, do your homework! Use proven data and logic, not thoughts and feelings. Ask for their insight and input. C-types appreciate and prefer emails in advance describing details and the reason for upcoming meetings. Resist the urge for small talk or chitchat.

Famous C-style communicator: Condoleezza Rice

Conclusion

Human behavior is complex, but it is also observable and predictable. As you can see, achieving effective communication and building effective teams in the workplace may be more easily attained than one believes. Using DISC makes achieving business goals, building relationships, and fostering customer satisfaction more attainable. Start improving communication skills and building better relationships by putting this tool and these tips into practice today!

For more information about common DISC combinations, visit https://www.revivecareers.com/resources.

Reference

1. Marston, W. M. 1928. *Emotions of Normal People*. London, UK: K. Paul, Trench, Trubner & Co. Ltd.

National Concrete Bridge Council—Promoting Concrete Bridges for the Industry

by Gregg Freeby, American Segmental Bridge Institute

The National Concrete Bridge Council (NCBC) is a council of allied concrete industry organizations dedicated to expanding the concrete bridge market through promotion of the benefits of concrete bridges. But NCBC's mission goes beyond expanding the market. The organization also promotes quality in concrete bridge construction and preservation by gathering and disseminating information on design, construction, and condition assessment of concrete bridges; establishing and maintaining communication with federal and state departments of transportation, city and county public works departments, consulting engineers, contractors, and material suppliers; and providing information on behalf of the concrete industries to codes and standards groups. NCBC membership is limited to trade associations serving the concrete bridge industry.

NCBC was founded in 1987 by representatives from four industry associations. Their first meeting with the Federal Highway Administration (FHWA) was on September 15, 1988. This meeting has continued as an annual tradition that enables the concrete bridge industry to collaborate with FHWA on various national initiatives and trends.

Since that first meeting, NCBC membership has grown. The nine current NCBC members and their representatives are as follows:

- American Segmental Bridge Institute, Gregg Freeby (chair)
- Concrete Reinforcing Steel Institute, Danielle Kleinhans
- Epoxy Interest Group of CRSI, Pete Fosnough (recording secretary)
- Expanded Shale, Clay and Slate Institute, Ken Harmon
- National Ready Mixed Concrete Association, Brian Killingsworth (vice chair)
- Precast/Prestressed Concrete Institute, William Nickas (past chair)
- Post-Tensioning Institute, Tony Johnson (treasurer)
- Silica Fume Association, Jim Wolsiefer
- Wire Reinforcement Institute, Paul Aubee

NCBC provides a unified voice for promoting concrete as the material of choice for all bridges in the United States. Council members work together on common projects to improve the quality, durability, and efficiency of concrete bridges to benefit the industry, taxpayers, and the traveling public. Through its member organizations, NCBC works closely with not only FHWA but also industry groups such as the American Association of State Highway and Transportation Officials (AASHTO), the American Concrete Institute, ASTM International, and *fib* (International Federation for Structural Concrete).

Concrete Bridge Views

In September 1997, NCBC signed a cooperative agreement with FHWA to assist in the transfer of knowledge and technology related to high-performance concrete (HPC) bridges that were being developed under the State Highway Research Program. The bimonthly publication *HPC Bridge Views* was one of the products of this agreement. As stated in the first issue (January/February 1999), "The purpose of the agreement is to develop and implement means to enhance the use and quality of concrete materials and bridge systems. This partnership will help us achieve a more cost-effective highway system."

The periodical was published about six times a year from January 1999 through April 2016. Its title was changed to *Concrete Bridge Views* with the January/February 2013 issue to reflect the fact that the use of HPC had become standard practice in many areas of the United States. NCBC maintains a website with all past editions of this periodical (http://concretebridgeviews.com), which continues to be an outstanding resource for information on HPC.

Primary Activities of NCBC

The primary activities of the council are intended to address issues at the national level as we collaborate with FHWA, AASHTO, and other organizations to accomplish the following:

- Resolve technical issues.
- Provide training, sponsor research, sponsor conferences, and seminars.
- Maintain and update the library of *Concrete Bridge Views* and other newsletters.
- Advocate for infrastructure funding and legislation that benefit concrete bridges.

The first meeting of the National Concrete Bridge Council and the Federal Highway Administration (FHWA) on September 15, 1988. Back row from left to right: Stan Gordon, Bob Nickerson, and Dr. Walter Podolny, all from FHWA; Dr. Basile Rabbat of the Portland Concrete Association; John Dick from PCI; and Ted Neff of the Concrete Reinforcing Steel Institute. Seated: Jim Rossberg from the National Ready Mixed Concrete Association. Photo: National Concrete Bridge Council.

NCBC also maintains a website (https://nationalconcretebridge.org), where information about upcoming NCBC events as well as links to resources available from member organizations can be found.

2021: A Turning Point

In November 2021, NCBC member representatives met in Washington, D.C., as they had for the past 34 years. But this meeting was different: there was mutually agreed-upon interest in expanding the mission of NCBC to become a more structured and purposeful organization. As a result, NCBC's Articles of Organization were revised for the first time in many years, a new slate of officers was approved, and the following four primary strategic objectives were adopted:

- Collaboration with AASHTO
- Collaboration with FHWA
- Collaboration with the Concrete Bridge Engineering Institute (CBEI)
- A focus on sustainability and resiliency

Collaboration with AASHTO

In July 2022, with the assistance of PCI, NCBC entered into a collaboration agreement with AASHTO. The objective of this agreement is for NCBC to work closely with the various AASHTO bridge technical committees to develop technical documents related to concrete bridges, including specifications, standards, policies, and other materials. Collectively, these materials will be cobranded by AASHTO and NCBC and made available through the AASHTO bookstore and the NCBC website. Initially, the following documents are envisioned: *Resources for Concrete Bridge Design and Construction, Guide to Post-tensioning for Transportation Structures*, and *Stewardship Guide for Concrete Structures*.

In addition to document development, NCBC is committed to supporting the technical committees of the AASHTO Committee on Bridges and Structures by providing technical support and guidance as needed. This includes supporting the T-4 Construction, T-5 Loads and Load Distribution, T-9 Bridge Preservation, and T-10 Concrete Design committees, as well as the Committee on Materials and Pavements.

Collaboration with FHWA

NCBC is committed to continuing its collaboration with FHWA, which began more than 30 years ago. NCBC will assist FHWA by hosting webinars, communicating the latest industry resources and research studies, and promoting "Every Day Counts" initiatives such as the deployment of ultra-high-performance concrete for bridge preservation and repair.

Collaboration with CBEI

NCBC aims to contribute to the success of CBEI through both financial contributions and the sharing of information on concrete bridge–related topics to identify mutually beneficial opportunities for the advancement of concrete bridges. More information about CBEI can be found in the Focus article in the Summer 2022 issue of *ASPIRE*® as well as on page 53 in this issue.

Sustainability and Resiliency

Sustainability and resiliency requirements are still emerging for the bridge industry. (See the articles about sustainability efforts in the concrete industry on pages 30 and 46 in this issue of *ASPIRE*.) While both the vertical construction industry and the pavements branch of the transportation industry have already made great strides in this area, the bridge community is very much in need of industry leadership. To that end, NCBC and its member organizations will be collaborating in the very near term with other transportation industry groups to help ensure that proper guidance on sustainability and resiliency is available to bridge practitioners.

NCBC Looks to the Future

In the 35 years since the inception of the National Concrete Bridge Council, there have been many changes in concrete bridges, but one thing remains the same: NCBC's commitment to improving our nation's infrastructure through concrete bridges. As new materials and technologies enter the marketplace, NCBC will continue to help communicate these innovations to bridge professionals.

A Call to Action for the Entire Concrete Industry—Including Bridges

Introducing NEU: An ACI Center of Excellence for Carbon Neutral Concrete

by Dr. Andrea Schokker, American Concrete Institute

Despite the vast amount of work done by the concrete industry to reduce our carbon footprint, concrete continues to have challenges with public and policy-maker perception. We in the industry know that we have more to do; at the same time, the image of concrete as "bad for the environment" needs to shift to an understanding of the opportunity we have and the part we must continue to play in reducing concrete's global carbon footprint. In particular, the discussion must go beyond just embodied carbon and address the resiliency benefits and long-term reduction in energy use that a concrete solution can provide. Near-term solutions must be realistic and ready to scale to the enormous demands of our industry.

The concrete industry is complicated, with significant regional variation and availability. Policy makers are pushing for solutions now, and without our input, the proposals often look like one-size-fits-all attempts that simply cannot work beyond the region where the limits are developed. We have already missed the opportunity to get in front of this type of legislation in some parts of the United States, but we can catch up and lead future efforts if we work together as a united front.

Center of Excellence for Carbon Neutral Concrete

The American Concrete Institute (ACI) has established NEU as an ACI Center of Excellence for Carbon Neutral Concrete to drive research, education, awareness, and global adoption of the use of carbon-neutral materials and technologies in the built environment. Established by ACI this spring, NEU leverages ACI's role as a world-leading authority and resource for the development, dissemination, and adoption of consensus-based standards for concrete design, construction, and materials. NEU is envisioned as an opportunity for new carbon-reduction technologies to enter the concrete industry, and it can direct necessary resources to accelerate the adoption of those technologies. Most importantly, NEU can build on the large amount of work that has already been done throughout the concrete industry to provide a unified front to the public, policy makers, and all those interested in how concrete can play a role in a carbon-neutral future.

To achieve NEU's goal of providing access to the technologies and knowledge needed to effectively and safely produce and place carbon-neutral concrete in the built environment, the following core functions have been established:

- Technology acceleration
- Technology transfer and professional development
- Technology assessment and validation
- Coordination with ACI committees
- Advocacy and technical support
- International and student outreach

These core functions will enable NEU to work with other organizations to develop viable solutions that can be implemented quickly. NEU is also focused on leading a widespread change of culture in the concrete industry to drive these solutions as well as to help the public understand the

As an American Concrete Institute (ACI) Center of Excellence, NEU leverages ACI's role as a world-leading authority and resource for the development, dissemination, and adoption of consensus-based standards for concrete design, construction, and materials. All Photos and Figures: NEU.

	NEU Board Seat	Special project options	NEU SDC Seat	Discounts on NEU products	Access to NEU center documents
Sustaining Member	✓	✓	✓	✓	✓
Supporting Member	—	—	✓	✓	✓
*Affiliate Member	—	—	*	✓	✓

*Opportunity for election to an at-large position on the NEU SDC
SDC = Strategic Development Committee

NEU offers three membership tiers—sustaining, supporting, and affiliate—with different levels of participation and benefits.

significant role played by the concrete industry in achieving carbon neutrality.

Research on cement and concrete sustainability and resiliency is currently fragmented and lacks a clear common goal. Significant resources are being channeled into ideas and technologies that simply will never be implemented. High-risk, high-reward research has its place, but NEU will keep its focus on technologies that experts can support as being realistic, applicable, cost effective, and technologically effective. It will take a focused, informed, technologically advanced organization to develop the necessary technologies. NEU will assume that responsibility and work directly with other major entities worldwide to achieve the desired outcome.

NEU is well placed to lead this effort. It can draw upon ACI's global reputation and existing resources for education, certification, and code and standards development, as well as access to the enormous knowledge base provided by the ACI technical committees, to move quickly and unify the voice of the concrete industry. The funding for NEU is provided by a three-tier membership that includes owners, developers, producers, manufacturers, engineers, architects, contractors, and technical institutes. Two members, Meta and Breakthrough Energy, have already joined at the top-tier membership level of $500,000 per year. These first two top-tier members join our first second-tier member, Baker Concrete Construction, and several other parties are also discussing higher-level memberships. These initial members show that the investment of those within the construction industry, as well as those outside of the industry, can make important contributions toward achieving carbon-neutrality goals for concrete. We are also working with many organizations across the globe, including nonprofits and governmental agencies, that will participate as affiliate members. These organizations recognize the need for the industry worldwide to work together toward a common carbon-reduction goal. The Federación Interamericana del Cemento (FICEM) and ICC-Evaluation Services are the first two organizations to sign a memorandum of understanding with NEU. NEU has also joined the National Institute of Standards and Technology (NIST) Consortium for Measurements of Low Carbon Cements and Concrete.

Federación Interamericana del Cemento recently signed an agreement to work with NEU on reducing carbon in the concrete construction industry.

Engaging the Transportation Sector

While ACI has traditionally focused on buildings, parking structures, and other vertical structures, the scope of NEU goes beyond these applications to all uses of concrete globally. We are planning to actively engage the transportation sector as a critical component of this work. In particular, the bridge industry is hugely important as we continue to upgrade infrastructure with concrete as a resilient and sustainable solution. *ASPIRE*® has featured some excellent articles on these efforts and has highlighted some opportunities for the bridge community. (For example, see the Perspective articles in the Winter and Spring 2022 issues of *ASPIRE*.)

For future infrastructure spending, it is important that owners and the public know that funds spent on concrete are a good investment in our global future. We already have many of the tools needed to make an impact on the embodied carbon of new structures as well as significant benefits when considering the service life of concrete bridges.

The Call to Action

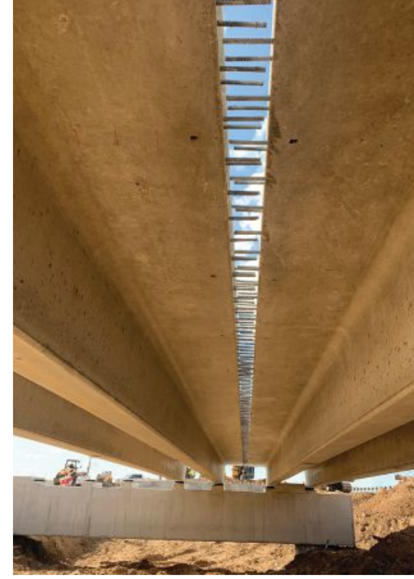
Our call to action at this moment in time is to come together with a common voice to change the perception of concrete so it becomes recognized as a sustainable and resilient solution for a carbon-neutral future. NEU is here to facilitate that transformation and to work with all components of our industry to move this initiative forward quickly. We will also work hard to address the roadblocks to advancement, whether real or perceived.

I hope you'll work with us to act now. As the technical consultant for NEU, one of my focus areas is as a liaison to the bridge industry, so please feel free to reach out to me. Learn more about NEU, including contact information and resources, by visiting the NEU website: https://www.neuconcrete.org.

PROJECT

Five Replacement Structures for the Texas Department of Transportation's Amarillo District

by Zachary Mayer, Texas Department of Transportation



The Texas Department of Transportation's (TxDOT's) Amarillo District covers 17 of the northernmost counties of the Texas Panhandle, known as the high plains. The district spans 17,848 mi^2 and maintains 840 bridges, including upgrades. TxDOT and its contractor recently completed the replacement of five bridge structures on U.S. Route 83 and State Highway 15 across three Amarillo District counties with 77 miles between the outermost bridges as the bird flies.

Placement of a precast concrete abutment at U.S. Route 83 over West Fork Horse Creek (South). All Photos and Figures: Texas Department of Transportation.

All five bridges were originally constructed in the 1930s, supported on timber piles. They were later widened in the 1960s to carry two lanes of traffic with 10 ft shoulders. Two of the bridges on U.S. Route 83 carried an average of 3500 vehicles per day. A third of that traffic volume consisted of 18-wheelers, while the remainder were mostly commuter vehicles between the cities of Perryton and Canadian in the northeastern portion of the panhandle. All five bridges were nearing the end of their service life.

Site Constraints and Project Concept

Early in the design concept meetings, it was determined that traditional construction methods would not be the best option for this project. Given the rural locations of the structures, alternative routes were limited. Available detours would range from 10 to 92 miles. Furthermore, right-of-way widths and site conditions would not allow on-site detours to be constructed at every location.

Because of those limitations, TxDOT decided to use accelerated bridge construction (ABC) methods. The TxDOT in-house design team investigated the various ABC options available, with the goal of making the bridges as similar to each other as possible.

Formwork for the ultra-high-performance concrete (UHPC) closure pours between NEXT D beams. This was the second project in Texas to use UHPC.

The drilled shaft sizes and placements, bents, abutments, and beam cross sections were identical for all five structures. A standard bridge width

profile

U.S. ROUTE 83 AND STATE HIGHWAY 15 BRIDGE REPLACEMENT PROJECT /
AMARILLO DISTRICT, TEXAS

BRIDGE DESIGN ENGINEERS: Initial design: Texas Department of Transportation, Austin, Tex.; alternate design: Thompson Engineering, Mobile, Ala.

OTHER CONSULTANTS: Plans, specifications, and estimates: Walter P Moore, McKinney, Tex.

PRIME CONTRACTOR: Webber LLC, The Woodlands, Tex.

PRECASTER: Texas Concrete Partners, Elm Mott, Tex.—a PCI-certified producer

OTHER MATERIAL SUPPLIERS: Ultra-high-performance concrete: Smart Up (material) and UHPC Solutions (installation)

New bridge before opening for traffic. Each structure went from start of demolition to being open to traffic in 10 to 12 days.

of 46 ft was used, and beam lengths were standardized to 60 or 70 ft. The bridges consisted of two to five spans and varied in total structure length from 140 to 300 ft.

Roadway vertical curves were adjusted such that grades along the decks were constant. This approach was designed to simplify construction, minimize the impact of the bridge replacement project on drivers, and decrease costs.

To limit the amount of work required on the approach pavement and decrease the effect of the project duration on the traveling public, vertical profiles were not adjusted more than 6 in. This allowed a hot-mix crew to complete the approaches for each bridge in a single day. The geometries of the existing roadways and their relations to the features being crossed meant that the structures did not require horizontal curves and could be built with no skew.

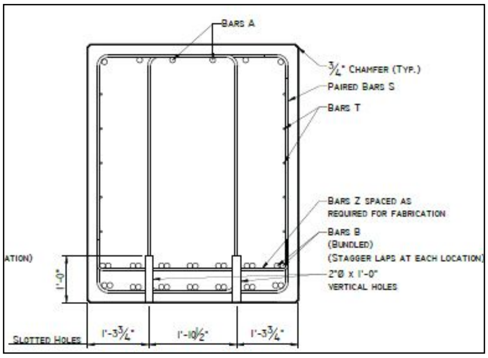
After putting together a preliminary set of plans, TxDOT met with several local bridge contractors. Construction processes, expectations, timelines, and alternative designs were all discussed. Concepts from these meetings were incorporated into the final design.

Placement of precast concrete bent cap. Two-column bents were used in combination with an oversized bent cap to allow construction of the drilled shafts before the bridge was demolished.

Substructure

The design of these structures required minimal removal of the existing structures to install the new drilled shafts. The abutments and bent caps were all precast concrete. Two-column bents were used in combination with an oversized bent cap so that drilled shafts and columns could be installed before each existing bridge was demolished. This strategy made it possible for much of the preliminary foundation work to be completed without disrupting traffic. It also allowed precast concrete bent caps to be placed on top of columns immediately after an existing structure was demolished. Each bent cap had slots where projecting

Section view of precast concrete bent cap. Each bent cap had holes where projecting reinforcing bars from the columns would connect into the caps.



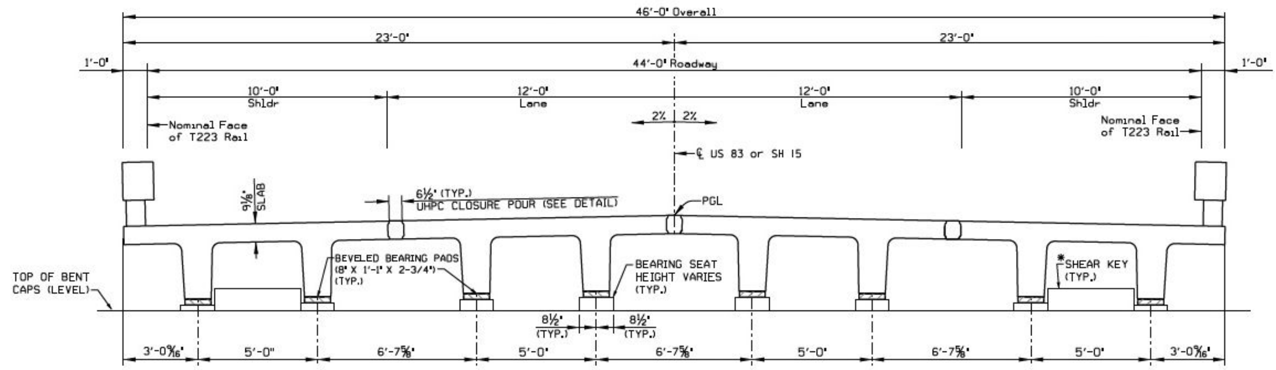
TEXAS DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTIONS:

- U.S. Route 83 at West Fork of Horse Creek (South), 210 ft long, three 70 ft spans
- U.S. Route 83 at West Fork of Horse Creek (North), 200 ft long, two 70 ft spans and one 60 ft span
- State Highway 15 at Farwell Creek, 140 ft long, two 70 ft spans
- State Highway 15 at Palo Duro Creek, 300 ft long, five 60 ft spans
- State Highway 15 at Ivanhoe Creek, 240 ft long, four 60 ft spans

STRUCTURAL COMPONENTS: 68 precast, prestressed concrete NEXT 36 D beams, 12 precast concrete bent caps, 10 precast concrete abutments with wingwalls, forty-four 48-in.-diameter drilled shafts

BRIDGE CONSTRUCTION COST: $168.95/ft^2



The bridge typical section shows the four NEXT 36 D beams, ultra-high-performance concrete closure joints, and the standard bridge width of 46 ft, which was used for all five bridges. The goal was to make the bridges as similar to each other as possible to optimize efficiency.

reinforcing bars from the columns would connect into the caps.

Superstructure

The project let with a proposed superstructure that consisted of four precast concrete deck units with an 11-ft 1⅛-in. wide deck with two precast concrete Tx28 I-girders per unit, with the precast concrete deck to be cast on site for camber considerations. Four of these units would be set side by side to create each span of the bridge, which provided the width for two lanes of traffic with 10 ft shoulders for each structure. The proposed bridge deck thickness was increased to 9 in. from TxDOT's standard bridge deck thickness of 8.5 in. The additional 0.5 in. was intended to be sacrificial to allow the completed bridge to be diamond-ground across the entire deck to ensure a good ride quality.

TxDOT specified that ultra-high-performance concrete (UHPC) be used between units to join the superstructure together. TxDOT's UHPC specification requires 14,000-psi compressive strength within 4 days and 21,000 psi within 28 days. This would be the second use of UHPC in Texas.

After the contract was let and awarded, the contractor approached TxDOT with several alternative designs. TxDOT allows post-let alternative designs for selected concrete elements to provide avenues for innovation with atypical precast concrete components. On this project, TxDOT partnered with the contractor and allowed the use of Northeast Extreme Tee (NEXT) beams, which are a type of double-tee beam (see the Creative Concrete Construction article on page 40 of this issue of *ASPIRE*®). Conceptually, the NEXT 36 D beam with 1 in. added to the top flange and TxDOT's proposed superstructure were very similar and used many of the same construction methods. Being able to construct the units at a precast concrete plant was a definite advantage. UHPC was still specified for the closure pours.

Conclusion

TxDOT's openness to using alternative designs fosters ingenuity and the development of new construction methods. In this case, it helped the contractor successfully navigate the site constraints and transportation challenges of this project. As a result, each structure went from start of demolition to being open to traffic in 10 to 12 days.

Zachary Mayer is the Pampa Area engineer for the Texas Department of Transportation.

Placement of NEXT 36 D beams.

The concrete for the T223 rail was placed on site using slip forming equipment.

An abutment is placed on the drilled shafts, which were installed before the road was closed to traffic.

Comments from TxDOT's Pampa Area Engineer, Zachary Mayer

In the design phase, I worked in the Transportation, Planning & Design (TP&D) department at the Amarillo District, Tex., headquarters. As the design project manager, I was tasked with developing a plan set package for these five bridges. While it is not unusual to bundle five bridges into one design project, it was still a juggling act—first, among the Texas Department of Transportation's Bridge Division, TP&D, and consultants, and again when the contractor made alternative recommendations.

At that time of design, I had no idea that I would be promoted to Pampa Area engineer and eventually oversee the construction aspect of this project as well. Moving from how I thought the project would unfold from the design aspect to how it actually came together in the construction process offered a unique opportunity to learn lessons that would have otherwise been missed. For instance, I have become more mindful of camber. Because there were so many aspects and entities involved, it was an opportunity to be reminded of areas where communication can be improved. These are lessons I look forward to carrying forward into future projects.

PROJECT

Southwest Light Rail Transit Project: Excelsior Boulevard Bridge

by Eric Nelson, AECOM

Metro Transit is the primary public transportation provider in the Minneapolis–Saint Paul, Minn., area, and a division of the Metropolitan Council. It operates the region's public transit, including two light rail transit lines—the METRO Blue Line and METRO Green Line—which serve more than 23 million passengers per year. In late 2018, with projected additional growth in the area, the Metropolitan Council began overseeing construction on an extension of the METRO Green Line, known as the Southwest Light Rail Transit (SWLRT) Project. The SWLRT Project is Minnesota's largest public works project to date, and the extended Green Line will operate from downtown Minneapolis to the southwest suburb of Eden Prairie. The total alignment is approximately 14.5 miles long with 16 new stations and more than 3.5 miles of bridge structure.

One of the signature bridges on the project is the dual-track Light Rail Transit (LRT) Excelsior Boulevard Bridge, which crosses over both Excelsior Boulevard and the Bass Lake Spur railroad in Hopkins, Minn. The alignment crosses the four-lane Excelsior Boulevard and a relocated portion of the Bass Lake Spur at relatively sharp skews. Accommodating these site features, coupled with local business owners' desire for open views beneath the bridge, dictated the need for long spans. In the preliminary layout, the bridge was envisioned as a concrete box-girder structure with most of the spans cast in place on falsework, and the span over Excelsior Boulevard constructed segmentally in a progressive-cantilever manner. However, the final design of this five-span bridge (244, 360, 400, 360, and 244 ft) used cast-in-place concrete segmental balanced-cantilever construction with form travelers. This design was selected because the local contractors have limited familiarity with constructing long, cast-in-place concrete spans on falsework, and because many bridges in Minnesota have been succesfully constructed using segmental balanced-cantilever designs.

Design Details

The superstructure of the bridge is a variable-depth, single-cell trapezoidal box girder. The maximum depth is 20 ft at the main span piers and 18 ft at the side span piers. The minimum depth is 8 ft at midspan with the section height varying parabolically. The box-girder

Long spans (up to 400 ft) of the Southwest Light Rail Transit Excelsior Boulevard Bridge accommodate site constraints for both roadway and railroad crossings while also providing open views beneath the bridge in an urban environment. All Photos: AECOM.

profile

BRIDGE 27C10 OVER EXCELSIOR BOULEVARD FOR THE SOUTHWEST LIGHT RAIL TRANSIT PROJECT / HOPKINS, MINNESOTA

BRIDGE DESIGN ENGINEER: AECOM, Nashville, Tenn.

OTHER CONSULTANTS: Construction engineering services: Finley Engineering Group (now COWI), Tallahassee, Fla.; geotechnical engineer: American Engineering Testing, Saint Paul, Minn.

PRIME CONTRACTOR: Lunda Construction and C.S. McCrossan Joint Venture, Minneapolis, Minn.

CONCRETE SUPPLIER: Aggregate Industries, Egan, Minn.

Construction of both cantilevers at the first pier uses a form traveler at each end. A temporary support is visible at the pier, and the portion of the first span that was cast on falsework is visible in the background. The bridge is close to an active freight rail line, which, once relocated, will be within 15 ft of the new structure in some locations.

webs have a constant thickness of 1 ft 6 in. and are inclined on a constant slope, creating a varying bottom slab width. The bottom slab thickness also varies, with a maximum thickness of 3 ft at the piers and a minimum of 10 in. at midspan. The top slab is cantilevered approximately 8 ft 6 in. beyond the webs, with the distance between the webs at the top slab set to align with the distance between the centerlines of the two tracks on the structure. This configuration minimizes transverse bending effects in the box-girder section under LRT live loads.

The profile grade and horizontal alignment for the structure are controlled by the geometry of the eastbound track, which is offset 7 ft 0 in. from the centerline of the bridge. This track geometry places almost the entire structure in a vertical curve, with 5% grades at each end. The horizontal geometry of the track in this area consists of several spiral curves that transition to both left- and right-turning large-radius circular curves with radii varying from 4000 to 10,000 ft. To facilitate the layout and construction of the box-girder segments, a horizontal alignment along the centerline of the bridge consisting of a series of circular curves that closely mimic the spiral and circular curves of the track alignment was developed.

The box-girder segments are cast with a movable form traveler in a balanced-cantilever fashion with no more than one-half segment length out of balance at any time. The main span cantilever at piers 2 and 3 has 10 segments extending out on each side of the pier table, with all segments being 16 ft 9 in. in length. The maximum segment weight, including fresh concrete and reinforcement, is approximately 305 kip. The cantilevers at side piers 1 and 4 are composed of nine segments on each side of the piers, with an approximately 60-ft-long portion of the end spans at the abutments built on falsework. Closure segments vary in length from 5 ft 9 in. at the side spans to 13 ft 0 in. at the center span.

All post-tensioning tendons are internal to the concrete superstructure. A combination of cantilever and continuity tendons, all housed within plastic ducts and subsequently filled with prepackaged grout, are used longitudinally. Two top slab longitudinal cantilever tendons composed of eleven 0.6-in.-diameter strands are used for each cantilever segment cast. Eight continuity tendons in the center three spans and six continuity tendons in the end spans are provided

Continuity post-tensioning tendons, which are internal to the box-girder webs, are anchored on each side of the pier diaphragm. External tendon hardware for future post-tensioning is anchored in the middle of the diaphragm.

METROPOLITAN COUNCIL / SAINT PAUL, MINNESOTA, OWNER

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

OTHER MATERIAL SUPPLIERS: Bearings: D.S. Brown, North Baltimore, Ohio; prepackaged grout: Euclid Chemical, Cleveland, Ohio; form travelers: NRS, Oslo, Norway; formwork: PERI Formwork Systems, Chicago, Ill.

BRIDGE DESCRIPTION: Five-span, 1608-ft-long, post-tensioned, cast-in-place concrete segmental box-girder bridge with spans of 244, 360, 400, 360, and 244 ft.

STRUCTURAL COMPONENTS: Single-cell cast-in-place concrete box-girder segments that vary in depth from 20 to 8 ft, cast-in-place concrete piers and abutments, and steel H-pile foundations.

A ballasted, temporary stability prop located under the fourth segment on the longer side of the cantilever is used to provide rotational stability for the box-girder span and resist uplift during balanced-cantilever construction. In the background of the photo, the portion of the span connecting to the abutment is being cast on falsework.

All reinforcement in the box-girder superstructure is epoxy coated for durability. Although deicing salts will not be used on the light rail structure, there is potential for chloride exposure given its proximity to adjacent roadways. The worker is installing a longitudinal post-tensioning duct in the last cantilever segment adjacent to a closure pour location.

within the webs that extend the full length of the spans along a parabolic profile. The tendons are composed of twenty-five and twenty-seven 0.6-in.-diameter strands. Bottom slab tendons are also provided; they use fifteen to nineteen 0.6-in.-diameter strands anchored within intermediate blisters in each of the spans. The relatively narrow width of the box section limited placement of anchorages in the pier diaphragms as well as the number of tendons that could be deviated in segment ribs. Therefore, external draped continuity tendons—which are common for this type of bridge—were not used, except to provide the needed anchorage and duct hardware for future post-tensioning as required by the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*. The top slab is transversely post-tensioned with three 4-strand tendons in plastic ducts for every 16-ft 9-in.-long segment.

The specified concrete compressive strength for the superstructure is 7500 psi, with minimum 4000-psi strength required before tensioning the post-tensioning tendons and advancing the form traveler.

Although deicing salts will not be used on the LRT structure itself, there is the potential for chloride exposure because of the proximity of the bridge to adjacent roadways. To minimize corrosion risk, epoxy-coated reinforcement is used in the superstructure. To mitigate stray current corrosion issues, galvanized steel stray-current collector cables were placed the full length of the bridge beneath each track plinth, bonded to all the post-tensioning anchors, and grounded at the abutments. The collector cables are kept electrically isolated and are not bonded to the epoxy-coated reinforcement in the segments.

Short Piers with Bearings

The substructure is composed of conventionally reinforced cast-in-place concrete piers founded on steel H-piles driven to bedrock. The piers are relatively short, ranging from approximately 8 ft tall at pier 1 to approximately 24 ft 6 in. tall at pier 3. For cast-in-place segmental bridges, tall, slender piers, such as twin-wall piers, are often cast integrally with the superstructure to provide strength and stiffness during cantilever construction; these piers are also longitudinally flexible to accommodate creep, shrinkage, and thermal effects without creating excessive loads on the foundation. However, on the Excelsior Boulevard Bridge, the piers were too short for such a solution. Therefore, to minimize foundation forces, the superstructure is supported with disc bearings that are free to move longitudinally at the piers and abutments except at pier 2, which has fixed longitudinal bearings. Two bearings are provided at each pier with vertical service limit state capacities of up to 5150 kip per bearing. One bearing per pier is multidirectional, and the other is unidirectional (guided) to restrain transverse displacements while allowing longitudinal displacements.

The disc bearing details electrically isolate the substructure from the superstructure so no special stray-current corrosion-

To reduce demands on the foundations, disc bearings free to move longitudinally are used to support the superstructure at all but one pier.

Balanced-cantilever construction with form travelers nears completion. The final closure pour of the 1608-ft-long, post-tensioned, cast-in-place concrete segmental box-girder bridge will be at this location in span 2 over Excelsior Boulevard, after the cantilever is completed.

control measures were needed for the piers and footings. Epoxy-coated reinforcement was used in the piers and abutments for enhanced atmospheric corrosion protection, and plain uncoated reinforcement was used in the pier footings. Architectural textures and other features were added to the concrete piers and abutments to achieve the overall visual quality requirements for the project. Additionally, after construction is complete, all visible elements of both the substructure and superstructure will receive a gray-colored finish coating.

Collision Resiliency

Based on the proximity of the Excelsior Boulevard Bridge to both the roadway of Excelsior Boulevard, which crosses under the bridge between piers 1 and 2, and the Bass Lake Spur, which runs parallel to and will cross under the bridge between piers 3 and 4 after it is relocated, all piers and both abutments are designed to resist 600-kip vehicle and train collision forces per the governing AASHTO and American Railway Engineering and Maintenance-of-Way Association design codes. Additionally, the foundations for the piers and abutments were evaluated for the addition of live-load surcharge from the adjacent railroad track, which in some locations is within 15 ft of the bridge structure.

Form Travelers and Props

Construction on the bridge began in fall 2019 with pile-driving operations. Construction of the superstructure is currently nearing completion. Four form travelers are being used, allowing two cantilevers to be constructed simultaneously. The original design envisioned that the final bridge closure pour would be completed in the center of span 3; however, after construction had commenced, the contractor opted to complete the longer cantilevers at piers 2 and 3 first, then the side-span cantilevers at piers 1 and 4, with the final closure pour to complete the bridge in span 2. The concrete superstructure was cast during approximately eight to nine months out of the year, with enclosures and heating elements used in the colder late-fall season. Construction was paused in the harshest winter months. Currently, all cantilevers and closure segments have been cast, except for cantilever 1, which was expected to be completed in late summer 2022.

With the superstructure being supported on piers with bearings, temporary supports were needed to allow cantilever construction; the contractor elected to provide stability using two types of temporary supports. The first type consisted of falsework bearing directly on the pier footing installed on both sides of the pier table, which provided rotational stiffness to complete cantilever construction for the first four segments on either side of the pier. The second type was a stability prop consisting of steel pipe columns bearing on a spread footing with added ballast to resist uplift. This prop and added ballast were installed beneath the fourth segment on the longer side of the cantilever to complete the remainder of the segments.

Construction of the Excelsior Boulevard Bridge, including all finishing and rail work, is expected to be completed in 2023, with revenue service on the entire SWLRT line expected in 2027. Once complete, the new LRT structure will be part of a system providing reliable public transportation for thousands of people every day in the Minneapolis–Saint Paul area.

Eric Nelson is a lead bridge design engineer with AECOM in Nashville, Tenn.

PROJECT

Rodanthe "Jug Handle" Bridge: Ensuring a Reliable Connection to the Southern Outer Banks

by Jeremy Keene, RK&K

This aerial photo looking north along the 2.5-mile-long Rodanthe "Jug Handle" Bridge was taken in May 2022 before the bridge was opened. The Atlantic Ocean is on the right. All Photos and Figures: RK&K.

The new $145 million, 2.5-mile-long "Jug Handle" bridge replaces a battered stretch of roadway from the Pea Island National Wildlife Refuge to the town of Rodanthe, N.C., by spanning westward over the Pamlico Sound. Situated on Hatteras Island in the picturesque Outer Banks of North Carolina, Rodanthe is a popular destination for vacationers, kiteboarders, and fishers. Most of these visitors travel to the Outer Banks by way of North Carolina Highway 12 (NC 12), a two-lane roadway that sits just above sea level. NC 12 is the only land access and is designated as a hurricane evacuation route. The stretch of NC 12 just north of Rodanthe is referred to by the locals as the "S" curves and is often flooded by hurricanes, nor'easters, and non-storm-related tidal events. Breaches of the dunes that separate the roadway from the Atlantic Ocean are common, and when the road is inundated with sand and water, it can be closed for prolonged periods. The roadway requires nearly constant clearing of sand and maintenance of the protective dunes to remain open.

Seeking a solution to alleviate these challenges, the North Carolina Department of Transportation (NCDOT) issued a request for proposal (RFP) to replace the roadway with a bridge designed for a 100-year service life and 105-mph winds.

There is a potential for large waves to impact the bridge if a breach of the barrier island occurs. Historical data and design storms indicated the potential for waves to reach an elevation of 17 ft above sea level. Any portion of the structure below that elevation needed to be designed for these forces.

As part of the initial preparation for design, the design team compiled a two-dimensional profile of the subsurface soil conditions and scour zones along the bridge profile from the boring information. A thorough review of this profile and the RFP requirements allowed the team to divide the bridge into five separate regions for design. The south approach, south curve, tangent, north curve, and north approach spans were investigated separately with respect to span layouts, superstructure design, scour profiles, and substructure design.

The new structure is designed to survive hurricane waves and collisions with empty barges, and it can remain in service with

profile

RODANTHE "JUG HANDLE" BRIDGE / DARE COUNTY, NORTH CAROLINA

BRIDGE DESIGN ENGINEER: RK&K, Raleigh, N.C.

CONSTRUCTION ENGINEER: Flatiron, Broomfield, Colo.

PRIME CONTRACTOR: Flatiron, Morrisville, N.C.

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

An overhead gantry working from an advancing rail system parallel to the outside edge of the bridge after it lifts a prestressed concrete cylinder pile from a vehicle on the completed portion of the bridge and moves it ahead to be installed. The 54-in.-diameter prestressed concrete cylinder piles, with lengths up to 165 ft, were used for the foundations of the bridge's main spans.

a breach of the barrier island resulting in scour up to 52 ft below sea level. To achieve the 100-year service life, the bridge has stainless steel reinforcing bars in most cast-in-place elements, epoxy-coated reinforcement in the parapets, additional cover on the reinforcement, additional corrosion inhibitors in all of the concrete, and stainless steel for any exposed hardware, including anchor bolts and bridge-mounted signposts.

Why Precast Concrete?

Given the harsh saltwater environment, the designers quickly decided to use precast concrete bridge components. Concrete's corrosion resistance in a saltwater environment reduces long-term maintenance costs and extends the life of the bridge. NCDOT's requirements for corrosion-inhibiting additives in the concrete mixture further enhance the concrete's resistance to corrosion.

Additionally, the design-build team aimed to use similar bridge components in all design regions to simplify detailing and streamline the precasting process. Widespread use of precast concrete components was advantageous given the bridge's remote location. All piles, Florida I-beam (FIB) girders, voided-slab units, deck panels, and concrete sheet piles were fabricated at a controlled precasting facility off site, which increased the quality of the products.

The use of precast concrete components sped up construction of the bridge. On-time delivery of the precast concrete components enabled the contractor to build simultaneously from the north and south headings, doubling the work area and accelerating the construction schedule.

Substructure

All superstructure units are supported on precast, prestressed concrete pile bents

Two innovative advancing rail systems, one from each heading, were used to construct the bridge. This strategy, which included an open-grate deck, reduced the project's temporary environmental impact by minimizing the shade cast on subaquatic vegetation beds. The rail-mounted gantries are visible on the right side of the photo. Note that the temporary rail system has advanced and no longer extends to the shore.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER EQUIPMENT SUPPLIER: Gantries, pile-tripping frame, custom rail bogies: DEAL, Italy

BRIDGE DESCRIPTION: A 12,987-ft-long bridge consisting of 10 spans of precast, prestressed concrete voided-slab units with spans up to 60 ft, and 97 spans of precast, prestressed concrete Florida I-beam girders with spans up to 137 ft

STRUCTURAL COMPONENTS: 45- and 72-in.-deep prestressed concrete Florida I-beam girders; 8400 ft of 24-in.-deep prestressed concrete voided slabs; 445,925 ft^2 of 5-in.-thick precast, prestressed concrete deck panels; 3940 ft of 30-in.-square prestressed concrete piles; 42,525 ft of 54-in.-diameter precast concrete cylinder piles; 156,290 ft^3 of cast-in-place concrete pile caps

Approach spans used 24-in.-deep prestressed concrete voided slabs on bents with 30-in.-square prestressed concrete piles.

with cast-in-place (CIP) concrete bent caps. The north and south approach span regions are supported by five vertical, 30-in.-square prestressed concrete piles embedded into a reinforced CIP concrete cap. The south curve, tangent, and north curve regions are supported by three 54-in.-diameter prestressed concrete cylinder piles. The exterior piles are battered transversely away from the centerline of the bridge at a 1:12 ratio while the center pile is vertical. These driven piles have a CIP concrete plug and cap connection that transfers moment and axial loads to the piles while providing a robust impact zone for the design vessel-collision forces and other lateral forces.

Several measures were taken to enhance the corrosion protection of the CIP substructure components. Stainless steel reinforcement was used with increased concrete cover for the cap and shear keys. Calcium nitrite corrosion inhibitor was added to both the precast and CIP concrete components to help achieve the 100-year service life requirements.

Lateral force resistance was a significant challenge for the substructure design. Several soil-structure interaction models were developed, and an analysis was performed for each of the design segments that considered the stiffness of the bents, vessel collisions, wave forces, and other external forces on the structure. Various models in the finite element analysis program FB-MultiPier also considered the full-scour and no-scour conditions and the applicable loads for the investigated cases. (For details on the analysis of barge collisions with bridges, see the Concrete Bridge Technology article in the Summer 2019 issue of *ASPIRE*®).

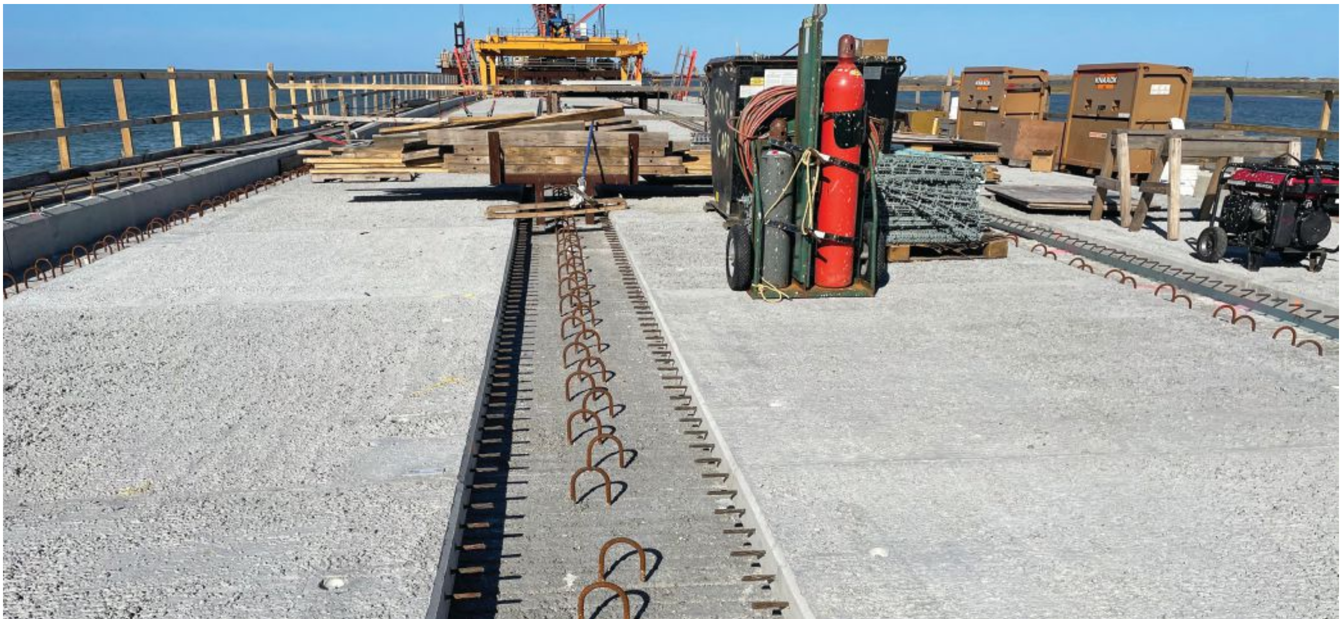
Superstructure

The bridge's typical section consists of two 12-ft-wide travel lanes and two 8-ft-wide outside shoulders. A concrete parapet with a two-bar metal rail protects the traveling public from the waters of the Pamlico Sound. The resulting out-to-out width of the bridge is 42 ft 7 in. North and south approach spans have superstructures that include a series of 24-in.-deep precast concrete voided-slab units that are post-tensioned together transversely and topped with a CIP concrete wearing surface. These voided-slab units are anchored on each end to the substructure with two 1-in.-diameter stainless steel anchor bolts and a hold-down plate to prevent the slabs from lifting off as a result of wave forces.

The south curve of the bridge is a more traditional bridge design, with four prestressed concrete, 45-in.-deep FIB girders at 12 ft 6 in. spacing with 5-in.-thick precast, prestressed concrete deck panels overlayed with a 5.5-in.-thick CIP concrete deck surface. All reinforcement in the CIP deck is stainless steel, which provides additional corrosion resistance to achieve the 100-year service life requirement. The use of 45 in. FIB girders allowed the team to optimize the span lengths for the tighter radius section while maintaining a similar girder spacing to the tangent and north curve sections of the bridge. In addition, the south curve span arrangement crosses over a historic sunken barge in the Pamlico Sound.

In areas where the low chord of the superstructure is above the maximum design wave height, the superstructure-to-substructure connections were designed to eliminate steel anchor bolts by using reinforced concrete shear keys. The design of the shear keys and diaphragms ensures all transverse and longitudinal forces are transferred efficiently between the superstructure and substructure components. Stainless steel, 2-in.-diameter anchor bolts and stainless steel bearing plates are employed in areas where the low chord elevation of the superstructure is below the maximum design wave height.

A close-up of the 5-in.-thick prestressed concrete deck panels on Florida I-beams. The roughened surfaces and stirrups protruding from the beams provide the shear interface between the cast-in-place deck and precast concrete components necessary for the composite action of the superstructure.



Prestressed concrete 5-in.-thick deck panels were used extensively in the main spans of the bridge. Large shear keys on the cast-in-place concrete caps allow the girders to resist wave loads. The panels are supported by prestressed concrete Florida I-beam girders, which are supported by precast, prestressed concrete pile bents with cast-in-place concrete bent caps. The exterior girders have a curb section cast on the top flange, which will support the deck screed. A portion of the advancing rail system that runs parallel to the bridge is visible in the foreground.

The tangent and north curve sections of the bridge also have 5-in.-thick precast, prestressed concrete deck panels and a 5.5-in. CIP concrete wearing surface. These spans are supported by four 72-in.-deep FIB girders spaced at 12 ft 11 in. For the exterior girders of the tangent spans, a precast concrete curb was used to reduce overhang falsework and support the screed rail during casting of the CIP bridge deck. Similar to the south curve, the span lengths of the tangent and north curve spans were optimized to take advantage of the full capacity of the FIB girders.

The design team optimized the design of the bridge components and provided an economical and constructible structure for the client by modeling the typical four-span continuous unit in FB-MultiPier. This model provided an accurate structural response for the bridge for use in optimizing the design.

Construction Methods

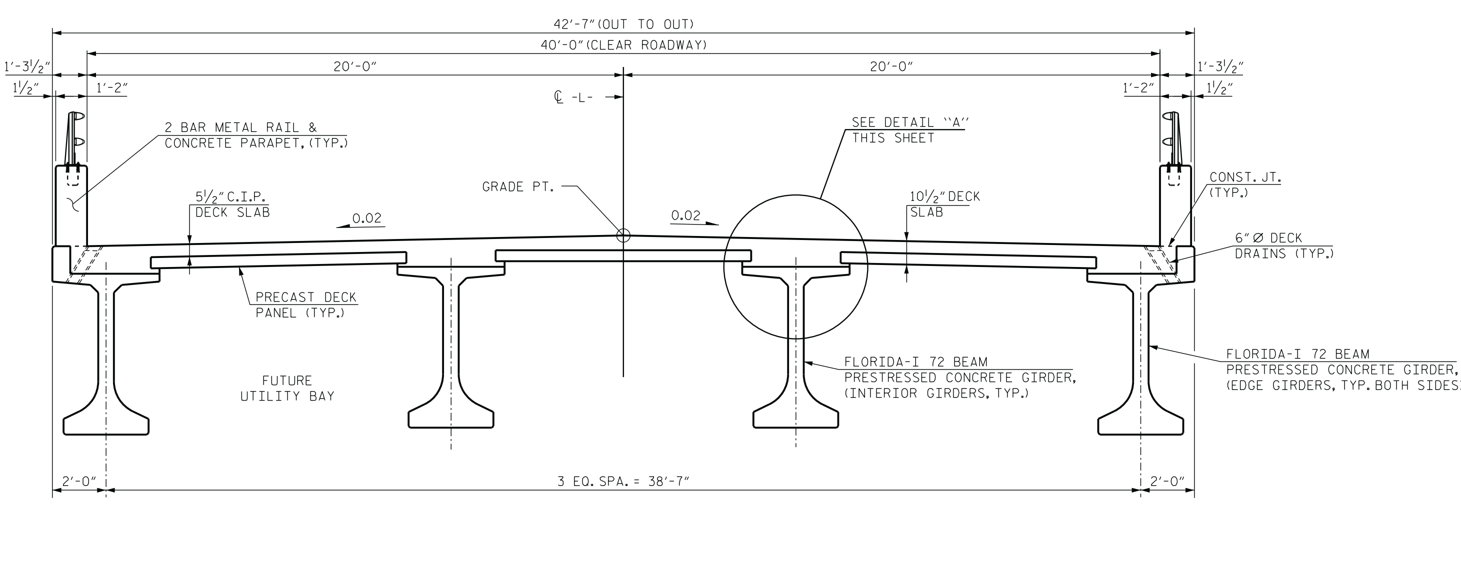
Construction means and methods for this structure were carefully thought out. With tidal water depths averaging between 2 and 4 ft throughout the length of the bridge alignment, working from barges or the ground was not feasible. Because this area is adjacent to the Pea Island National Wildlife Refuge and contains subaquatic vegetation throughout the project footprint, the project team had to meet stringent rules and regulations related to environmental impacts. The requirement to maximize sunlight in the areas under work trestles also limited the possibilities of working platforms. These restrictions led the team to develop a construction method that would exceed the environmental requirements. An advancing rail system parallel to the outside edge of the permanent bridge superstructure was used to build the bridge. Gantries that moved along the 1600 ft advancing rail lines carried the precast concrete bridge components and other materials for installation. The use of precast concrete components with this gantry system reduced construction times and allowed the contractor to build one span per week at the north and south headings under optimal conditions.

Conclusion

The Rodanthe "Jug Handle" Bridge is a significant structure that was constructed in a harsh marine environment under strict construction tolerances and designed to reach a 100-year service life. To significantly enhance the quality and performance of the structure, the project used a broad array of precast concrete components, including 0.78 miles of 30-in.-square precast concrete piles, 8.00 miles of 54-in. precast concrete cylinder piles, 9.34 miles of precast concrete FIB girders, and 445,925 ft^2 of precast concrete deck panels. The use of precast concrete components in conjunction with the advancing rail system for construction enabled the contractor to construct the bridge economically. The contractor's bid was $145.3 million. A dedication ceremony and community day was held on April 9, 2022, with the new bridge opened to traffic on July 28, 2022.

Jeremy Keene is a project delivery leader with RK&K in Raleigh, N.C.

The bridge's typical section consists of two 12-ft-wide travel lanes and two 8-ft-wide outside shoulders. A concrete parapet with a two-bar metal rail protects the traveling public from the waters of the Pamlico Sound.



The Time to Begin Addressing the Environmental Impacts of Bridge Construction Is Now

by Emily Lorenz

EDITOR'S NOTE

Articles related to bridge preservation have appeared in the Concrete Bridge Preservation series since 2010. While preservation remains a key focus of ASPIRE®, we have recognized that the series needs to be expanded to also address other important topics such as sustainability, resiliency, and system management. Therefore, we are introducing the rebranded series, Concrete Bridge Stewardship, which will encompass the wider scope of topics. Please contact us at info@aspirebridge.org to let us know what you think, and to send us your ideas for topics.

When PCI issued its first guidance related to sustainability and precast concrete back in 2010,[1] it focused primarily on best practices related to sustainable building design made popular by the LEED rating system. As the precast concrete industry and others sought to determine the environmental impacts of their products and systems, they undertook life-cycle assessments (LCAs) and developed environmental product declarations (EPDs) to transparently report the results. Yet this revolution of sustainability-minded thinking in the building industry is only just awakening in the transportation market. This article discusses the current state of practice in the transportation market related to sustainability as well as where the industry might be headed in the near future based on precedents in the building market.

Starting at the Beginning

Even though it has been 35 years since the Brundtland Commission of the United Nations defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs,"[2] the design and construction communities still struggle to define sustainability.

As a concept, sustainability is often associated with three principles—referred to as three pillars—namely, economy, society, and environment. As the sustainability movement has gained momentum in the construction industry, the focus has been primarily on the environmental pillar.

There are several reasons for this focus on the environment. Societal impacts are more difficult to quantify than environmental ones, and there are fewer internationally recognized and objective indicators in the building market related to the market's impact on society. For infrastructure projects, societal impacts are more likely to be considered in terms of public benefit or inconvenience. This trend is changing in the building market, however, as indicators for societal impacts related to equity and inclusion are increasingly being developed.

Economic impacts have not been the focus of sustainable design because economics usually take care of themselves in a capitalist society: owners will generally not go forward with design choices that they cannot afford.

Thus, the emphasis on environmental impacts has been due to the relative ease of their quantification (compared with societal impacts) and because they had not previously been the focus of design decisions (unlike economic impacts). LCA is a well-defined, straightforward way to quantify environmental impact potentials. As a methodology, LCA has been used in practice for decades, and the standards that define LCA (ISO 14040[3] and ISO 14044[4]) are internationally recognized and used. LCA

Key Sustainability Terms

Environmental product declaration (EPD): A Type III environmental label (defined by ISO 14025[5]) that is peer-reviewed and reports the findings of a life-cycle assessment (LCA). EPDs developed for products for buildings and civil engineering works must conform to ISO 21930.[6]

Global warming potential (GWP): An environmental impact category that "describes potential changes in local, regional, or global surface temperatures caused by an increased concentration of GHGs [greenhouse gases] in the atmosphere, which traps heat from solar radiation through the 'greenhouse effect.'"[7] The gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are considered greenhouse gases; therefore, they can be grouped together in the GWP impact category. In terms of GWP, 1 lb of CH_4 is 30 times more potent than 1 lb of CO_2, and 1 lb of N_2O is 298 times more potent than 1 lb of CO_2. Therefore, CO_2 is assigned a weighting factor of 1, CH_4 a factor of 30, and N_2O a factor of 298. GWP is reported in terms of carbon dioxide equivalent, CO_2e.

Embodied carbon: The GWP from the following life-cycle stages: raw material extraction, transportation, manufacturing, construction, maintenance, renovation, and end of life. It includes the GWP from all life-cycle stages except those due to operational energy use.

can be used to quantify environmental impacts for a complicated system, such as a building or bridge, or for a simple product, such as a bolt.

LEED Rating System for Buildings

The LEED rating system, developed by the U.S. Green Building Council, is partly responsible for the "sustainability awakening" within the design and construction industry in the building market. Its simplified, point-based system is accessible for designers seeking to reduce environmental impacts in their designs. The system also has the added benefit of familiarizing designers with the basics of sustainability.

In the LEED system, the categories for earning points—such as increased recycled content, using local materials, and reusing materials—were based on trends realized from past work in LCA. The developers of the LEED system knew that, *in general*,

- recycled-content and reused materials have less environmental impact than virgin materials, and
- local materials require less transportation, and therefore have less environmental impact, than materials shipped from farther away.

The LEED rating system thus encourages reductions in environmental impacts without having to educate designers in the building market about the intricacies of LCA.

Rating Systems in the Transportation Industry

In 2010, when the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure launched the ENVISION rating system, they saw the advantages of a simplified approach for infrastructure projects and therefore mimicked the LEED rating system. Federal and state agencies also began developing programs to educate and raise awareness within the infrastructure design community on sustainable design principles.

One of the more mature sustainability-related programs within the Federal Highway Administration (FHWA) is the Sustainable Pavement Program (SPP). Beginning with workshops in the late 2000s, two roadmaps and many programs have been created to educate stakeholders and to develop tools for design and construction of more-sustainable pavements. Like sustainability efforts in the building industry, the SPP focuses more on reducing environmental impacts and less on societal impacts. But, unique to the transportation industry, a focus on life-cycle cost accounting (LCCA) is also part of the SPP roadmap.

Based on the latest roadmap published by FHWA,[8] four goal areas have been developed: pavement systems, assessing pavement sustainability, guidance and outreach, and implementation. Several resources were also developed, including the following:

- A sustainable pavement design reference document
- Starter guidelines on how to implement LCA
- Tech briefs and training on LCCA, LCA, and other sustainability-related topics
- Case studies on sustainable pavements
- A free LCA software tool, LCA Pave, specifically for pavements

Unfortunately, FHWA does not have a program similar to SPP for bridges. But the bridge industry can efficiently develop the tools it needs to assess the sustainability of bridges based on past work in the building and pavement industries.

Current Procurement Regulations Affecting the Transportation Industry

The time of overlooking the environmental impacts of our bridges is coming to an end. The federal government, as well as the public, will increasingly be requiring engineers to minimize the environmental impacts of bridge designs. In December 2021, President Biden issued executive order (EO) 14057, "Catalyzing Clean Energy Industries and Jobs through Federal Sustainability."[9] Goal 5 of the EO focuses on net-zero emissions from federal procurement, including a "Buy Clean" policy to promote the use of construction materials with lower embodied-carbon emissions. Passed in November 2021, the Infrastructure Investment and Jobs Act includes a focus on low-carbon technologies. In addition, states are also implementing Buy Clean or green procurement laws for public projects.

As these laws are applied, contractors, bridge engineers, and material suppliers will need to understand basic concepts related to sustainability and how to meet the legal requirements. Given the increasing threat of climate change, much of the focus of these Buy Clean or green specification requirements has been on reducing the greenhouse gas emissions related to products and projects.

As an example of green specification requirements, the General Services Administration (GSA) has issued new national standards[10] for low embodied-carbon for ready-mixed concrete and asphalt in response to EO 14057. These requirements apply to

> ***all GSA projects, both capital and small, regardless of funding source: paving upgrades, modernizations, new construction, customer-funded projects through BA80 Reimbursable Work Authorizations, privately financed projects such as Energy Savings Performance Contracts, and all*** *Bipartisan Infrastructure Law* ***projects.***[11]

The standard for concrete requires construction contractors to submit EPDs to verify the global warming potential (GWP) requirements of the standard have been met (**Table 1**).

The numbers used in the GSA standards are also significant because they are an example of green specification requirements that were developed incorrectly. The GSA references benchmark GWP values from a report by the New Buildings Institute that were developed based on a geographically limited data set and without any industry input.[12] Without an understanding of regional differences among concrete suppliers, these benchmark values may be easy for all producers to meet in one part of the United States, and nearly impossible to meet in another part. A better starting point for the GSA numbers would have been the GWP values developed by the National Ready Mixed Concrete Association (NRMCA).[13]

Marin County, Calif., is attributed as the first jurisdiction in the United

Table 1. Maximum global warming potential limits for the General Services Administration's low embodied-carbon concrete

Specified concrete compressive strength, psi	Maximum global warming potential limits, kg CO_2e/m^3		
	Standard concrete	High-early-strength concrete	Lightweight concrete
Up to 2499	242	326	462
2500 to 3499	306	413	462
3500 to 4499	346	466	501
4500 to 5499	385	519	540
5500 to 6499	404	546	N/A
6500 and up	414	544	N/A

Source: Data from the General Services Administration (2021).
Note: These values reflect a 20% reduction from global warming potential (CO_2e) limits in proposed code language from the New Buildings Institute (2022). N/A = not applicable. 1 kg = 2.205 lb; 1 m^3 = 1.308 yd^3; 1 psi = 6.895 kPa.

States to develop a low-embodied-carbon concrete code.[14] And while many jurisdictions would like to "copy" what Marin County did, few understand the background of how those GWP numbers were developed. When researching what GWP limits to use in Marin County, an advisory committee analyzed local GWP data from averages supplied by NRMCA—an LCA practitioner—and 400 mixture proportions used by structural engineers through the Structural Engineers Association of Northern California. From that data analysis, the committee developed GWP limits that were applicable to their region.

Another output of the Marin County process was the development of a summary document that identifies keys to success for setting GWP limits, including the following important considerations,[15] which were not followed by GSA in developing its guidelines:

- *Consider the range of projects and ensure that the code structure is accessible by all affected project types.*
- *Conduct a review of existing mixes by engaging local engineers and concrete suppliers.*
- *Compare these findings to a benchmark such as the NRMCA averages, and take into account that regional mixes vary by availability and quality of raw materials for concrete; environmental conditions that may require different concrete performance; standards of practice; and market economics. The findings for the Bay Area will be different from other regions.*

This list of points illustrates why it is important for all of us in the concrete bridge industry—suppliers, contractors, owners, engineers—to understand how environmental impacts are calculated and what makes sense from a benchmarking perspective.

Getting Up to Speed

Owners, bridge engineers, contractors, material suppliers, and procurement specialists should begin by educating themselves on the basics of sustainability. Many of the available resources related to general sustainability concepts are applicable to the bridge market. Chapter 1 of the *PCI Bridge Design Manual*[16] contains a primer on sustainability concepts related to bridges.

Once they are familiar with basic concepts, bridge industry professionals should feel more comfortable educating themselves on more advanced topics such as LCA, EPDs, and how to compare or create benchmarks for the environmental impacts of bridge systems.

To increase competence in the area of sustainability, the bridge industry can do the following:

- Prioritize sustainability education at industry events.
- Develop a framework for LCA for bridges that applies across all materials.
- Write and disseminate articles and case studies about successes in the industry.

The transportation industry has the opportunity to improve the environmental impacts of our bridges and infrastructure. But it cannot wait to implement sustainability concepts any longer. The time to act is now.

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Iowa's Bridge Asset Management Strategy and Resources for Bridge Preservation

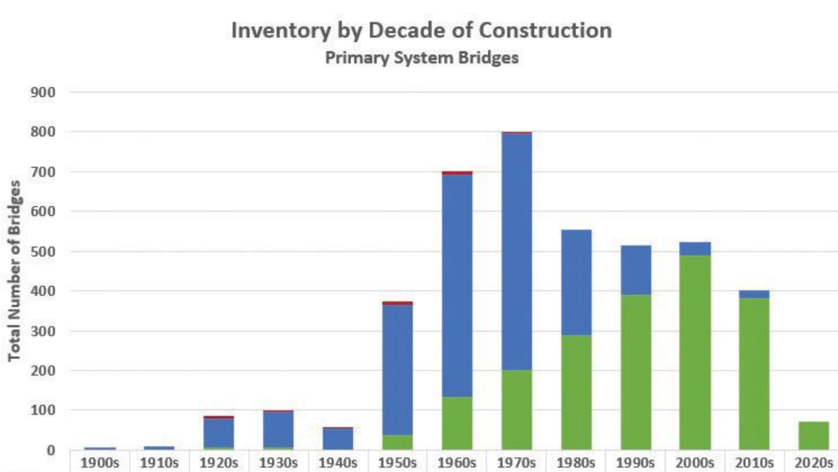
by Jim Nelson, Iowa Department of Transportation

Maintaining an inventory of bridges in a state of good repair is no small feat given the tremendous demands on our transportation system. Challenges we face include the following:

- An aging bridge inventory
- Limited budgets for bridge stewardship and modernization
- Structural deterioration from the use of deicing chemicals
- Increasing traffic and truck volumes
- Expansion of the system to address capacity, delays, and congestion
- Resiliency concerns, such as those associated with longer, new bridges constructed to accommodate greater hydraulic openings
- The need to harden new and existing bridges to withstand natural events
- The need to accomodate the greater axle loads and gross vehicle weights that have been recently legalized

The State of Iowa has an inventory of 23,799 bridges, according to the National Bridge Inventory data submitted to Federal Highway Administration (FHWA) in March 2022. The state owns and maintains 4195 of those bridges on the primary road system, with the remainder being on secondary roads owned and maintained by local public agencies such as cities and counties. While the number of secondary road bridges in Iowa is nearly five times that of the primary system, the two systems are closely matched in terms of bridge deck area: the primary roads have more than 47 million ft^2 of bridge deck, and the secondary roads have more than 49 million ft^2.

The Iowa Department of Transportation (DOT) has made a concerted effort during the past decade to increase its focus on stewardship and address bridges classified as being in poor condition, and it has reduced the number of poor bridges in the primary system from 237 in 2009 to 30 in 2022. While this is good news, there is still significant pressure on the Iowa DOT to keep bridges in a state of good repair and not backslide on the number of poor bridges. To rate bridges, Iowa DOT uses a bridge-condition index that takes into account the bridge structural condition, load-carrying capacity, horizontal and vertical clearance, roadway width, traffic levels, type of roadway, and the length of detour if the bridge were closed. The index uses a 100-point scale and defines a bridge rated 50 or better as being in a state of good repair.



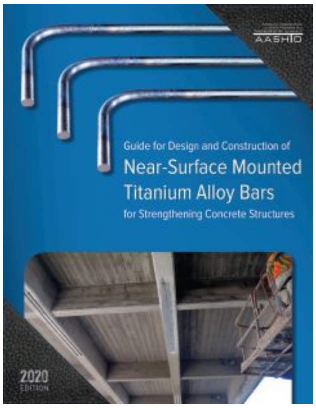
	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	2020s
Poor	0	0	6	2	2	8	9	3	0	0	0	0	0
Fair	6	11	71	88	56	325	558	596	267	123	34	19	0
Good	1	0	8	8	0	39	133	201	288	390	488	383	72

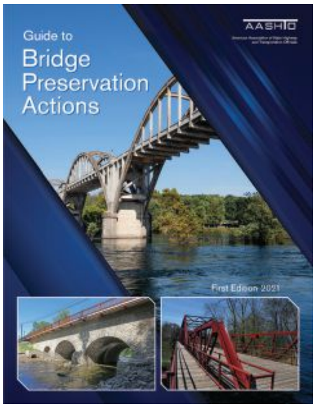
Figure 1. Conditions of primary system bridges in Iowa by decade of construction. Figure: Iowa Department of Transportation.

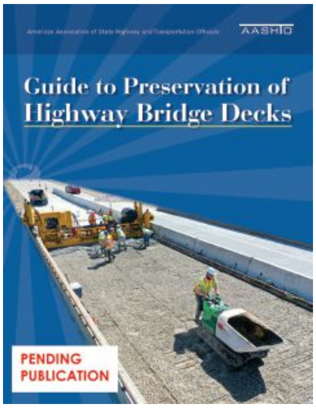
One of the biggest challenges to maintaining a state of good repair is our aging bridge inventory. **Figure 1** shows the number of primary system bridges built in each decade and the relative conditions of the structures. The data in Fig. 1 show a "bubble" of in-service bridges constructed in the 1960s and 1970s, many of which are now considered to be in fair condition. Over time, there is a risk that this large volume of fair-condition bridges will deteriorate into poor condition, thereby straining the stewardship funding resources of the state. To counter this risk, Iowa DOT is using a three-pronged bridge asset management strategy to maintain the primary system bridges in a state of good repair. This strategy includes the following actions:

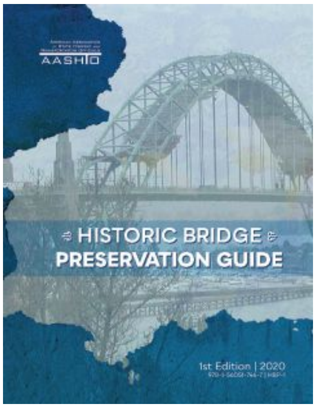
- Increasing bridge stewardship with an emphasis on more bridge replacements
- Investing in service-life design materials and details so that the bridges built today last longer than those built before the 1980s
- Investment in bridge preservation so that bridges in the current inventory last longer

Increased stewardship is primarily a function of funds available at the federal and state levels and how use of those funds is prioritized. There have









The covers of several new guides recently or soon to be published by the American Association of State Highway and Transportation Officials (AASHTO) with a focus on bridge preservation and rehabilitation. Photos: AASHTO.

been positive stories for Iowa with respect to funding. The first involves greater transportation revenue from a state fuel tax increase in 2015. The additional revenue is used to focus on projects critical to maintaining Iowa's transportation infrastructure. The second involves the Bipartisan Infrastructure Law, enacted in November 2021, which increases federal funding to the states for transportation infrastructure.

Improving the durability of bridges to achieve longer-lasting and lower-maintenance structures has been an ongoing effort and point of emphasis at Iowa DOT. This has resulted in the following:

- An increase in the number of jointless bridges through the use of integral or semi-integral abutments
- Use of high-performance concrete in bridge decks, where available, for improved (lower) permeability characteristics
- Improvements to pavement support corbels on abutment backwalls for durability
- Improvements to approach pavement details
- Use of materials such as stainless steel reinforcement for deck-to-barrier rail connections
- Use of stainless steel reinforcement on selected bridge decks and components where there is a goal to extend service life

Iowa DOT will continue to investigate and improve materials and details to achieve durable and long-lasting bridges. Emerging technologies that we continue to research and pilot include use of ultra-high-performance concrete, nonmetallic-fiber-reinforced concrete, and internal curing of concrete.

Bridge preservation is the area today where we see the most potential for gains in improved transportation asset management performance. Owing to funding restraints, reactive strategies that repair identified deterioration have traditionally been our primary preservation strategy, and such strategies will remain a priority.

Additionally, we are pursuing proactive preservation strategies to keep bridges in good or fair condition. Potential proactive strategies include replacing expansion joint seals that are reaching the end of their service life (before they leak); protecting new bridge decks with sealers or overlays (especially those that exhibit early-age cracking); and washing bridge decks, joints, drains, and bearing seats under joints to remove contaminants, thus slowing or eliminating further deterioration. The transition to a combination of both proactive and reactive strategies will be challenging to balance given the funding available.

Iowa DOT develops new policy and practices for bridge preservation based on institutional experience and information from an array of resources. Peer exchanges are valuable opportunities for learning (see the Creative Concrete Construction article on page 44 for methods and details to achieve a jointless structure that will minimize distress and improve bridge performance). Other key resources include the American Association of State Highway and Transportation Officials (AASHTO) Transportation System Preservation Technical Services Program, FHWA bridge preservation resources, and several new guides published by AASHTO with a focus on bridge preservation and rehabilitation. A brief introduction to some of these new AASHTO publications follows.

AASHTO's *Guide to Bridge Preservation Actions*[1] was published in July 2021 and is a product of the National Cooperative Highway Research Program (NCHRP) Project 14-36 (for details of this NCHRP project, see the Perspective article in the Spring 2021 issue of *ASPIRE*®). The guide contains an extensive list of bridge preservation actions that can be implemented to keep bridges in fair or good condition and provides guidance on choosing particular preservation actions and their expected effects on bridge conditions. The guide also presents a preservation-cycle cost analysis method to help owners evaluate the benefits of preservation and provides examples in the appendices.

Another product of NCHRP Project 14-36 is AASHTO's forthcoming *Guide to Preservation of Highway Bridge Decks.*[2] At the 2021 annual meeting of the AASHTO Committee on Bridges and Structures, the proposed guide was balloted and passed for adoption. Many bridges in the United States are in climates where temperatures fall below freezing, leading to damage caused by freezing and thawing as well as the application of deicing agents, which can shorten the service life of reinforced concrete. While some bridges are rarely exposed to freezing temperatures, all bridge decks are subjected to direct loading from vehicles and trucks. Because bridge decks are such a key bridge component and are aggressively attacked by the environment and usage, a specific guide dedicated to their preservation was considered a worthwhile objective. The guide focuses on preservation activities for steel-reinforced concrete bridge decks, which are the predominant bridge deck type in the United States, but it also provides guidance for timber decks and steel-grid decks. The format of the guide is very similar to that of the *Guide to Bridge Preservation Actions*[1] and contains details for over 20 potential preservation treatments for highway bridge decks. Look for this new resource to be published soon.

Historic bridges, such as those listed on the National Register of Historic Places or eligible for listing, present unique challenges for bridge owners. Such bridges are often iconic, complex structures that also serve as critical transportation links. Therefore, when owners pursue preservation and rehabilitation actions, they must balance bridge safety for the traveling public with respect for and protection of the structure's cultural and historical significance. The AASHTO *Historic Bridge Preservation Guide*[3] is a resource for bridge owners and engineers to help them navigate historic preservation laws and the need to maintain the safety and serviceability of these bridges. The guide covers loading and analysis considerations for historic structures and has chapters that offer component-specific guidance for concrete structures, steel and iron structures, railings, and more.

Another AASHTO publication relevant to bridge rehabilitation is the *Guide for Design and Construction of Near-Surface Mounted Titanium Alloy Bars for Strengthening Concrete Structures*.[4] This guide is based on research conducted by Oregon State University and the Oregon DOT. The titanium alloy discussed in the guide is highly corrosion resistant and has minimum yield stresses of 120 and 130 ksi for Classes 120 and 130, respectively, making it very suitable for near-surface mounted strengthening. The near-surface mounted titanium can be used for either shear or flexural strengthening of reinforced concrete. The guide contains design provisions for shear, flexure and bond, and anchorage, along with design examples and construction recommendations.

A good bridge asset management program that includes bridge preservation is a cost-effective way to maintain a bridge inventory in a state of good repair. Bridge preservation resources continue to be developed and AASHTO's set of guides can help bridge owners and engineers implement good practices for bridge preservation. The guides will continue to be maintained, and updated when necessary, by AASHTO. As Iowa DOT's bridge preservation program matures and we implement more proactive preservation practices, we expect to maintain our bridge inventory in a state of good repair more cost effectively and to see improvements in system operation reliability and safety, with fewer disruptions due to reactive repairs.

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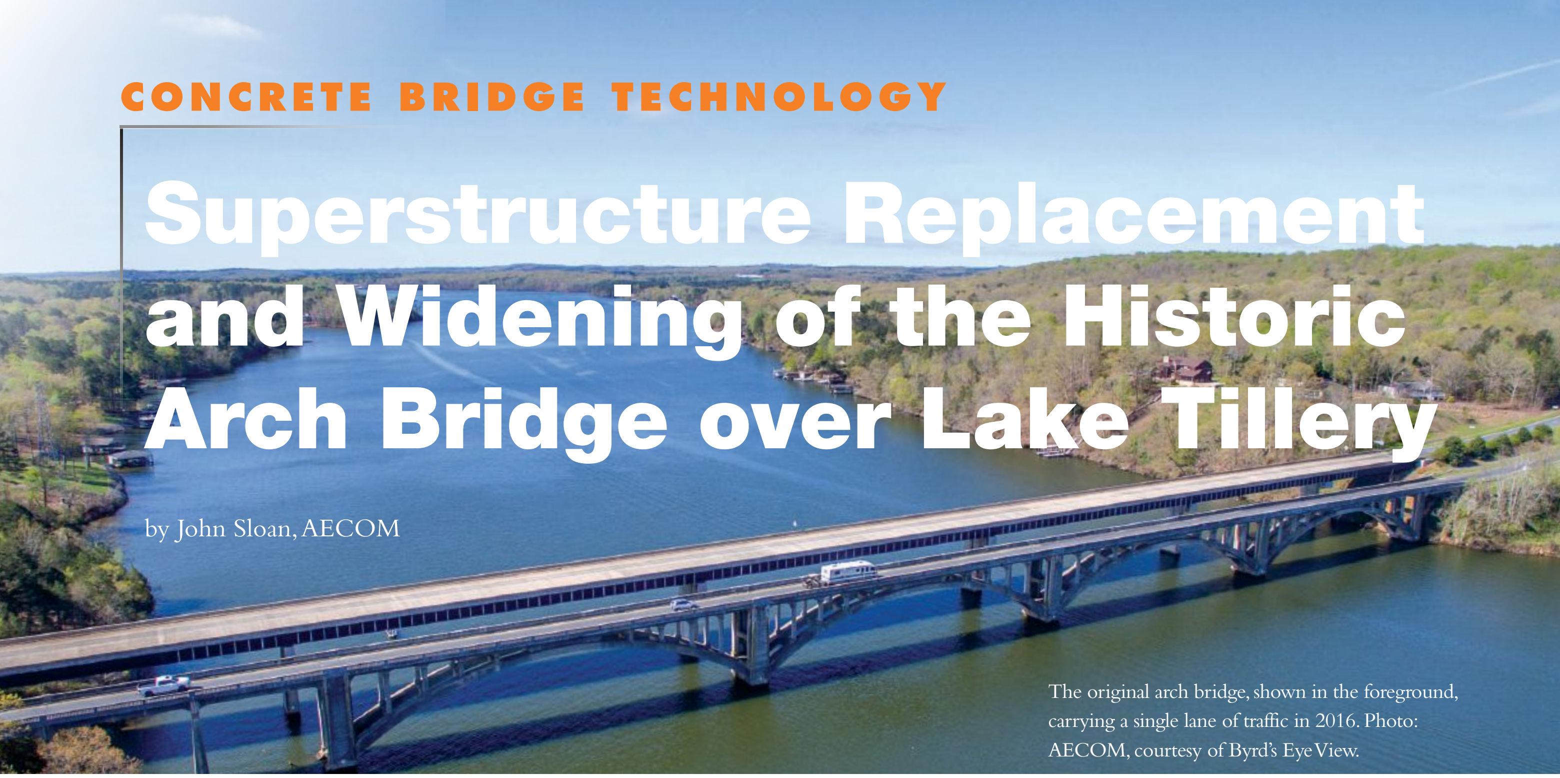
Superstructure Replacement and Widening of the Historic Arch Bridge over Lake Tillery

by John Sloan, AECOM



The original arch bridge, shown in the foreground, carrying a single lane of traffic in 2016. Photo: AECOM, courtesy of Byrd's Eye View.

The Lake Tillery Bridge was constructed northeast of Charlotte, N.C., in 1927. The open-spandrel arch bridge was originally intended for two-lane, two-way traffic. However, by 2015, the 20-ft-wide deck of the arch bridge was carrying only a single, westbound lane of traffic because adequate shoulder width was needed to improve safety. At that time, the historic bridge was within the limits of a larger road-widening project, and its owner, the North Carolina Department of Transportation (NCDOT), needed to decide what to do with it. Many options were considered, such as replacing the bridge altogether or turning the arch bridge into a bike and pedestrian facility while constructing a third bridge for additional vehicular traffic. NCDOT contracted with AECOM to perform a feasibility study to determine if the bridge could be widened to provide a 36-ft-wide roadway for vehicular traffic. The feasibility study evaluated whether the arches and piers could be preserved while replacing the superstructure to allow two westbound lanes with shoulders on the widened bridge. Other aspects of the Lake Tillery Bridge rehabilitation project were discussed in Project and Creative Concrete Construction articles in the Spring 2022 issue of *ASPIRE*®.

Feasibility Study

The feasibility study had four main parts. The first part involved a complete inspection of the structure, including above- and underwater portions. Although the inspection found significant deterioration of the bridge superstructure near the expansion joints, the arches and piers were in good condition, to the extent that even the grain imprint of the old timber formwork could be seen in some of the concrete.

The second part of the feasibility study was a material evaluation and service-life analysis. It was important to NCDOT that the arch bridge project result in a full 75-year service-life extension—the same duration as the service life for a new bridge. The material evaluation found the concrete to be in good condition, and the arches and piers were anticipated to achieve the desired service life of an additional 75 years.

The third part of the feasibility study included a two-dimensional load rating of the arches and piers under the original bridge configuration, and another load rating under the proposed configuration. This analysis demonstrated that the proposed configuration could work, and the load response of the arches could be improved by eliminating expansion joints and stiffening the superstructure.

In the final part of the feasibility study, the historic architecture of the bridge was evaluated. The team created renderings of the proposed structure for comparison with the original, and it was determined that the project would have no adverse effects on the historic structure, in accordance with the Historic Preservation Act. The superstructure replacement alternative was estimated to cost at least $4 million less than any other alternative, and NCDOT decided to move forward with final design of this alternative.

The new superstructure of the open-spandrel arch bridge in the foreground is wide enough to carry two lanes of traffic with shoulders. Photo: AECOM.

The original open-spandrel arch bridge had a 20-ft-wide deck. Photo: AECOM, courtesy of Byrd's Eye View.

The new superstructure of the rehabilitated bridge has a 36-ft-wide road surface. Establishing continuity of the prestressed concrete box beams from pier to pier before placing the concrete deck mitigated loadings on the arch ribs. Photo: AECOM.

Final Design

At the beginning of the final design phase, a laser survey was completed to confirm the geometry of the existing arch ribs and spandrel-column pedestals. Using the information from the survey, a four-dimensional finite element model of the bridge that included the nonlinear effects of the construction sequence was constructed. The team used this model for geometric control as the superstructure was removed and then replaced. The team also could account for geometric changes due to the removal and addition of loadings throughout the construction process. Because the dead load of the proposed superstructure was greater than that of the original, a detailed construction sequence was specified to prevent overstressing the arches during construction. This construction sequence ensured the new superstructure loads would be placed on the arches concentrically along the axis of the component. The arches are lightly reinforced compression components, so the concentric dead load improved their ability to resist live-load moments due to vehicular traffic. The model indicated that the arch ribs remained uncracked throughout the construction sequence and under live load; therefore, the design team used the full moment of inertia of the components without stiffness reductions.

The original superstructure had three reinforced concrete deck girders with steel plate bearings that bore directly on the spandrel bent caps, so this was a very rigid articulation. The superstructure had expansion joints at third points within each arch span, which created high moment demands in the arch ribs below these joints. In the final structure configuration, load was relieved from the arch ribs by establishing continuity of the prestressed concrete box beams from pier to pier before placing the concrete deck. This was achieved by providing continuity reinforcement and closure pours between the box beams over the spandrel bents. In addition, the stiffness of the proposed superstructure was significantly greater than that of the original. Tall elastomeric bearings with a much lower modulus of elasticity than the original steel bearings were used, which created a spring support at each spandrel bent, allowing the superstructure to flex and resist demands while further alleviating the demands on the arches. Collectively, these items created a greater level of redundancy in the proposed structure compared with the original articulation.

The original superstructure was removed during construction. A detailed construction sequence prevented overstress in the arches during construction. Photo: AECOM, courtesy of Aerial Photo Pros.

Concrete Preservation

Material preservation was an important aspect in the final design. Discrete anodes were used in concrete patches to mitigate the effects of chlorides in the concrete located below the expansion joints in the original superstructure. A cementitious jacket was specified for the piers at the waterline to repair wear and scaling caused by surface waves during the bridge's previous 90 years of service. A breathable sealer was applied to the entire structure to help preserve the original concrete and to create a uniform appearance among new, original, and repair concretes. The elimination of 15 expansion joints from the original bridge aids the preservation of the structure.

Construction

NCDOT hired PCL as the contractor for the Lake Tillery project, and AECOM served as NCDOT's engineer during the construction phase of the project. The team collaborated successfully to complete the rehabilitation and open the historic arch bridge to traffic in August 2022. With its efficient structural design and anticipated full service-life extension of 75 years, this project provided NCDOT with significant savings compared with other alternatives, improved connectivity within the region, and maintained the historic and architectural character of the original bridge.

John Sloan is the North Carolina bridge program manager for AECOM in Raleigh, N.C.

Precast Concrete Components Save Time and Money on Texas Bridge Replacements

by David Tomley and Justin Yard, Texas Concrete Partners, LP, and
Luis Amigo, Fernando Pellico, and Luis Rodriguez, Webber

Precast concrete bent caps and abutments were part of the accelerated bridge construction strategy that allowed the construction team to deliver the project under budget and ahead of schedule. All Photos and Figures: Texas Concrete Partners, LP.

When the Texas Department of Transportation (TxDOT) planned the replacement of the last five timber-pile supported bridges in the state-owned bridge inventory, the agency designed traditional prestressed concrete girder bridges to capitalize on their standardized details and durability (see the Project article on page 18). The prestressed girders were planned to be topped with cast-in-place (CIP) concrete decks and supported by conventional CIP substructure elements. However, the site constraints and long detour lengths led TxDOT to promote accelerated bridge construction (ABC) techniques for the completion of the two bridges on U.S. Route 83 (U.S. 83) and three bridges on Texas State Highway 15 (SH 15). After the plans went to bid, the contractor and precaster collaborated with TxDOT to maximize the use of precast concrete components, reducing both costs and duration of construction.

Contractor’s Perspective

Collaboration and innovation were two key factors in the success of this bridge replacement project. ABC techniques using precast concrete components, including Northeast Extreme Tee (NEXT) D beams as well as precast concrete abutments and caps, allowed the construction team to deliver this project under budget and ahead of schedule.

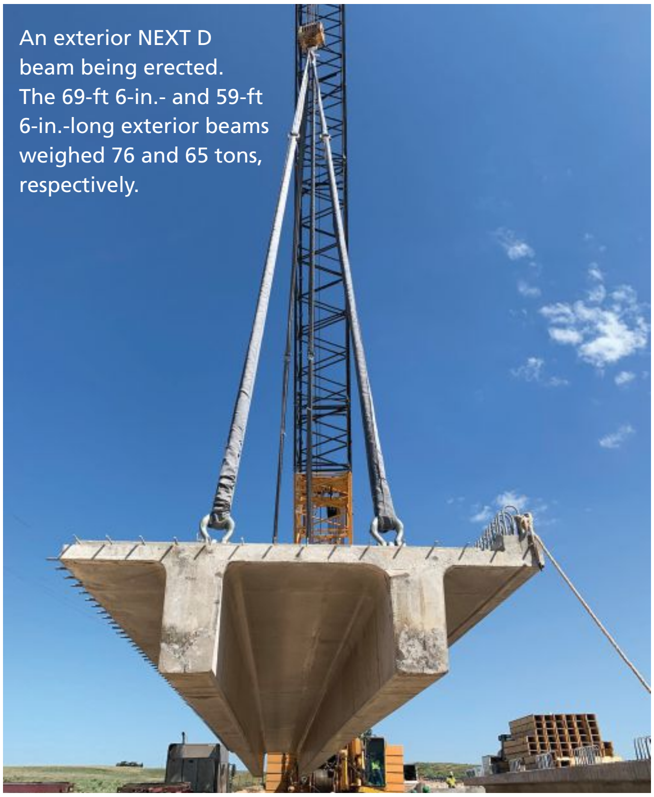
Minimizing Road Closures

The project involved replacing five existing bridges during extremely short traffic closures. Webber, the contractor, was able to demolish and rebuild each bridge with just 11 days of full traffic closures—40% faster than the allotted time.

Contractor's Proposed Innovation

The original contract plans included four decked-beam units that would be connected with ultra-high-performance concrete (UHPC) connections. Each unit included two Tx28 girders with a CIP concrete deck. The contractor proposed NEXT D beams in accordance with TxDOT’s *Alternate Precast or Accelerated Bridge Structure Standard Operating Procedures*.[1] The contract had an incentive/disincentive clause, so the contractor chose NEXT D beams mainly to reduce schedule risk.

The superstructures of the bridges were built with NEXT D beams, which are precast concrete double-tee beams with integral $9\frac{1}{8}$-in.-thick top flanges that compose the structural bridge deck. This enabled the 46-ft-wide superstructure to be built with only four beams joined together by UHPC closure pours. Additionally, the use of precast concrete abutment walls, wingwalls, and bent caps helped reduce road closures and construction impacts on motorists.



An exterior NEXT D beam being erected. The 69-ft 6-in.- and 59-ft 6-in.-long exterior beams weighed 76 and 65 tons, respectively.

Preparing to place concrete for the approach slab and the ultra-high-performance concrete longitudinal closure pours between NEXT D beams.

Setting a precast concrete abutment on the drilled-shaft foundations. Reinforcement extending from drilled shafts fits into ducts in the precast concrete cap, which are then grouted.

NEXT D beams stored at the precaster's plant. The top and bottom transverse reinforcement project from the sides of the top flange for the ultra-high-performance concrete closure pour. The top and bottom bars are staggered to avoid conflicts during erection. The notch in the top flange at the end of the beam is for a closure pour to make the flange continuous and avoid an open joint.

Webber improved upon the original design provided by TxDOT and coordinated their innovative ideas with the various players: project team, consultants, precaster, and TxDOT. Webber credits the success of this project to the joint efforts of everyone involved and the willingness of TxDOT to consider these innovative, alternate proposals.

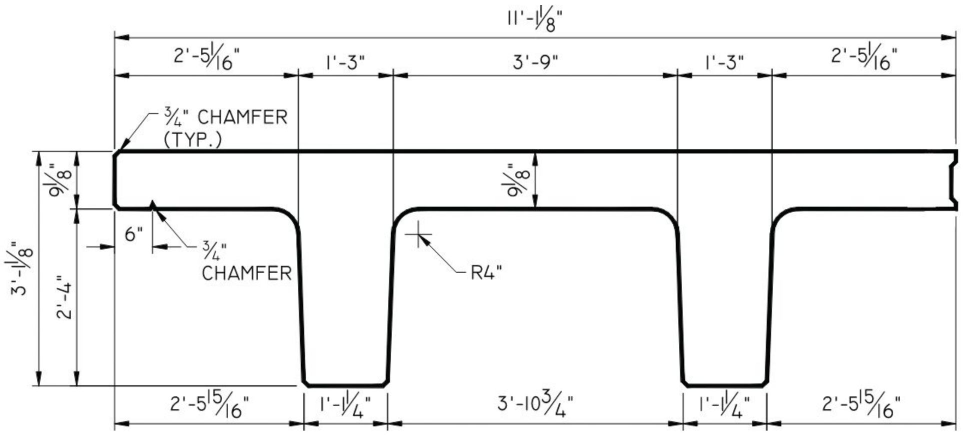
Precaster's Perspective

The project allowed the precaster, Texas Concrete Partners, an opportunity to invest in new forms to fabricate the precast, prestressed concrete NEXT D beams. The NEXT D beam self-stressing form can be customized to allow the top-flange thickness, top-flange width, and beam height to vary. The beam height can vary between 2 ft 4 in. and 3 ft 4½ in. Shallower beam heights can be fabricated by adding fillers inside the stems in the form. This flexibility allows the NEXT D beam section to be designed and fabricated to meet varying roadway widths, span lengths, or both.

The NEXT D beam section for all beams used on this project had a height of 3 ft 1⅛ in. and top-flange width of 11 ft 1⅛ in. The stems had a fixed spacing of 5.0 ft. For this project, the four NEXT D beams required for each span were able to accommodate a two-lane roadway transverse section with 10-ft shoulders and an out-to-out bridge width of 46 ft. The five bridges included a total of 4326 ft of nonskewed NEXT D beams: twenty-eight 69-ft 6-in.-long beams and forty 59-ft 6-in.-long beams.

The top flange of the beams functions as the deck and the final riding surface. The top flange thickness was increased from a more typical 8½ to

The 2¾-in.-thick elastomeric bearing pads are beveled 0.25 in. to match the 2% roadway cross slope and allow level bearing seats.



The NEXT D beam section used for all beams on this project. The NEXT D beam self-stressing form can be customized to allow the top-flange thickness, top-flange width, and beam height to vary. Given this flexibility, the NEXT D beam section can be designed and fabricated to meet varying roadway widths, span lengths, or both. The stem spacing is held constant at 5.0 ft. As shown here, the left side is an exterior face and the right side is an interior joint, which will receive an exposed aggregate finish for the ultra-high-performance concrete closure pour.

9⅛ in. to allow for diamond grinding after completion to meet TxDOT's Ride Quality for Pavement Surfaces requirements (Item 585).[2] The top and bottom transverse reinforcement in the top flange projected out of the side forms for the UHPC closure pour connection and consisted of hot-dip galvanized no. 5 bars at 9-in. spacing. The top and bottom bars were staggered to avoid conflicts during erection.

The shorter-span NEXT D beams contained thirty 0.6-in.-diameter prestressing strands with six debonded strands. The longer-span NEXT D beams had forty 0.6-in.-diameter prestressing strands with 10 debonded strands. All NEXT D beams had four fully tensioned, 0.6-in.-diameter prestressing strands in the top flange to reduce the top-flange tensile stresses at transfer (see the Concrete Bridge Technology article in the Summer 2018 issue of *ASPIRE*®). The 2¾-in. elastomeric bearing pads were tapered transversely 0.25 in. to match the 2% roadway cross slope. Whereas the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[3] does not allow tapering of elastomeric bearing pads, TxDOT permits it in certain situations. In this case, tapering the pads allowed the bearing seats of the precast concrete bent caps to be level (but with varying heights), which facilitated fabrication.

The same self-consolidating concrete (SCC) mixture proportions were used for all NEXT D beams. The SCC design strengths were 6.0 ksi at transfer and 8.5 ksi at 28 days. The average 28-day concrete strength achieved was 10.15 ksi (19.4% greater than required). The only difference between the exterior and interior NEXT D beams was the projecting reinforcement for the Type T223 traffic rail for the exterior beams.

For the UHPC connection, Texas Concrete Partners applied a surface retarder to the sides of the forms of the top flanges to provide an exposed-aggregate finish according to TxDOT's *Surface Finishes for Concrete* (Item 427).[4]

The NEXT D beams had no embeds other than lifting loops and coil-loop inserts that were provided in the bottom of the top flanges to facilitate forming of the UHPC connection.

Because camber was an important design and construction consideration, it was monitored with camber measurements taken at transfer and again each week at the plant. As-built elevations were taken after the NEXT D beams were erected to finalize the deck grinding plan.

The precast reinforced concrete interior bent caps were fabricated to meet a 4.6-ksi concrete design strength. A total of 12 precast reinforced concrete interior bent caps were fabricated. The cap dimensions were 4.5 × 5.5 × 50 ft with the shear keys and bearing seats placed monolithically with the cap. The bent caps were fabricated using a lightweight concrete with a unit weight of 126 lb/ft³. This reduced the overall cap weight from 106 tons (if normalweight concrete were used) to 86.4 tons, which minimized lifting requirements and transportation costs.

From the precaster's perspective, several factors motivated the use of NEXT D beams and precast concrete bent caps for this project: no skew, similar span configurations with only two beam lengths for the five bridges (seven 70-ft spans and ten 60-ft spans), same out-to-out bridge widths, and the same NEXT D beam section.

Conclusion

TxDOT was willing to consider and ultimately construct an alternate design that met the original contract requirements, although the girder section was not standard in Texas. This owner agency's flexibility and collaboration allowed the contractor to complete the project with less than 11 days of full traffic closures at each bridge location.

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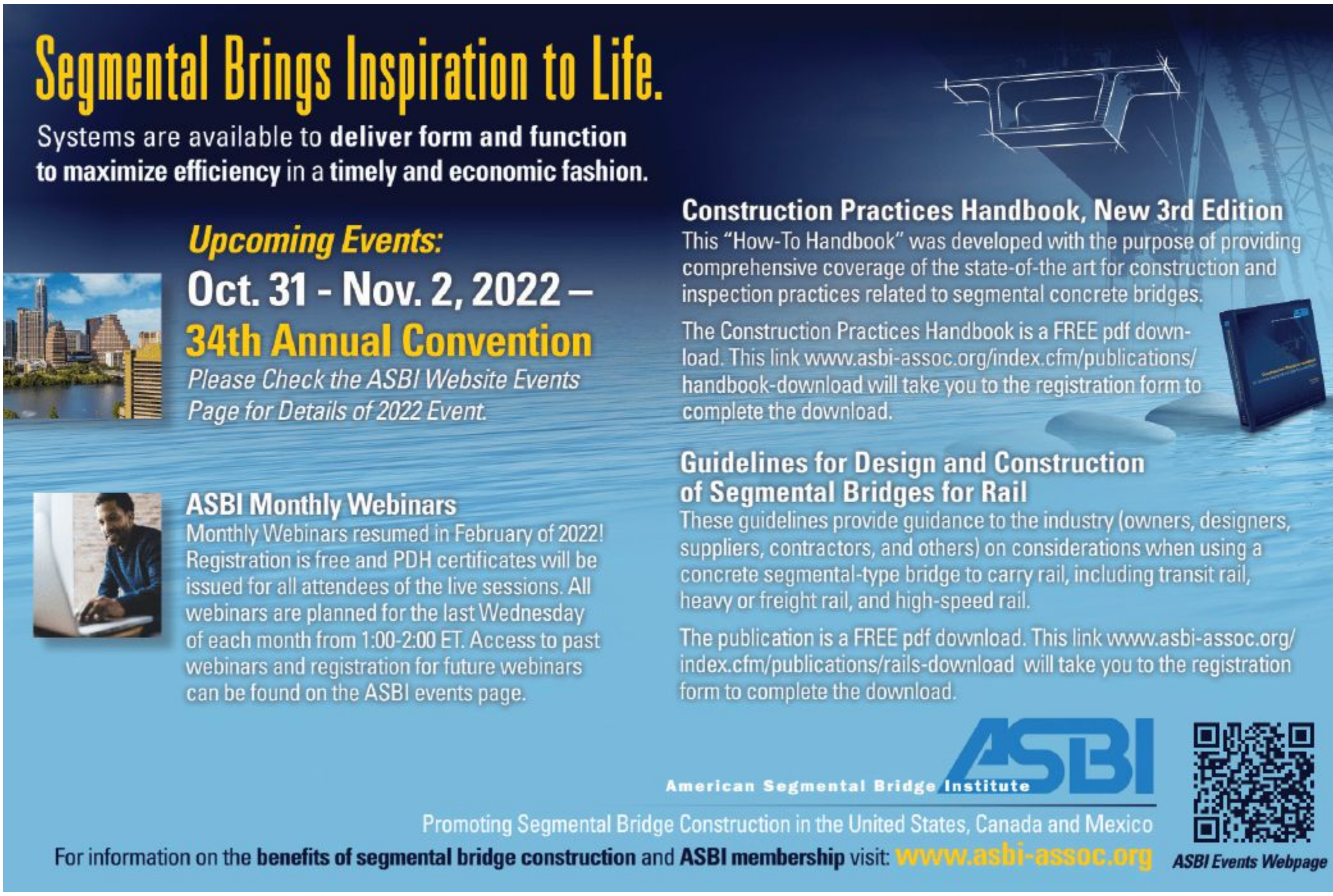
Using lightweight concrete for the bent caps reduced transportation costs and lifting requirements.



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The "Bump at the End of the Bridge": Findings of Scan 19-01

by Dr. Krista Brown

The objective of Scan 19-01 was to gather agencies' experiences with distresses observed on approaches to jointless bridges—the "bump at the end of the bridge." This article presents highlights of the scan and a few of the findings of the final report, *Leading Practices for Detailing Bridge Ends and Approach Pavements to Limit Distress and Deterioration*.[1]

What Is a Scan?

The Domestic Scan Program considers items of common interest to transportation agencies and facilitates the sharing of innovative practices. The program is funded through National Cooperative Highway Research Program (NCHRP) Project 20-68D. A scan team typically consists of eight to 12 members from the American Association of State Highway and Transportation Officials (AASHTO) member agencies and may include representatives from academia, the Federal Highway Administration (FHWA), industry, and other public organizations involved in the specific topic. The time allotted to carry out a scan is relatively short, about 12 to 15 months.

Scan 19-01

For Scan 19-01 the team consisted of representatives from five state departments of transportation (DOTs), one representative from FHWA, and a subject matter expert from academia. The team met in August 2019 to select the participating agencies and finalize the amplifying questions to pose to them. The participating DOTs were selected to include states with severe climates, active relevant research programs, unique design or retrofit procedures, a long history of integral pier use, and other criteria. **Figure 1** shows the states with members on the scan team and the participating DOTs.

The scan team studied the specific bridge components shown in **Fig. 2**. To collect and capture information on jointless bridges, amplifying questions were posed to the participating DOTs. The following is a sampling of the amplifying questions:

- How do you track system performance of jointless bridges?
- What details do you no longer use and why?
- Do you impose limits on span lengths or total bridge lengths for integral abutments?
- What is the approximate distribution (percentage) of your superstructures: steel, cast-in-place concrete, or precast concrete?
- What is your expansion joint detail on your approach slab-to-roadway pavement interface?
- Does your state design manual provide jointless bridge design guidance?
- Have you evaluated cost equivalency (for example, joint maintenance compared with a jointless bridge)?

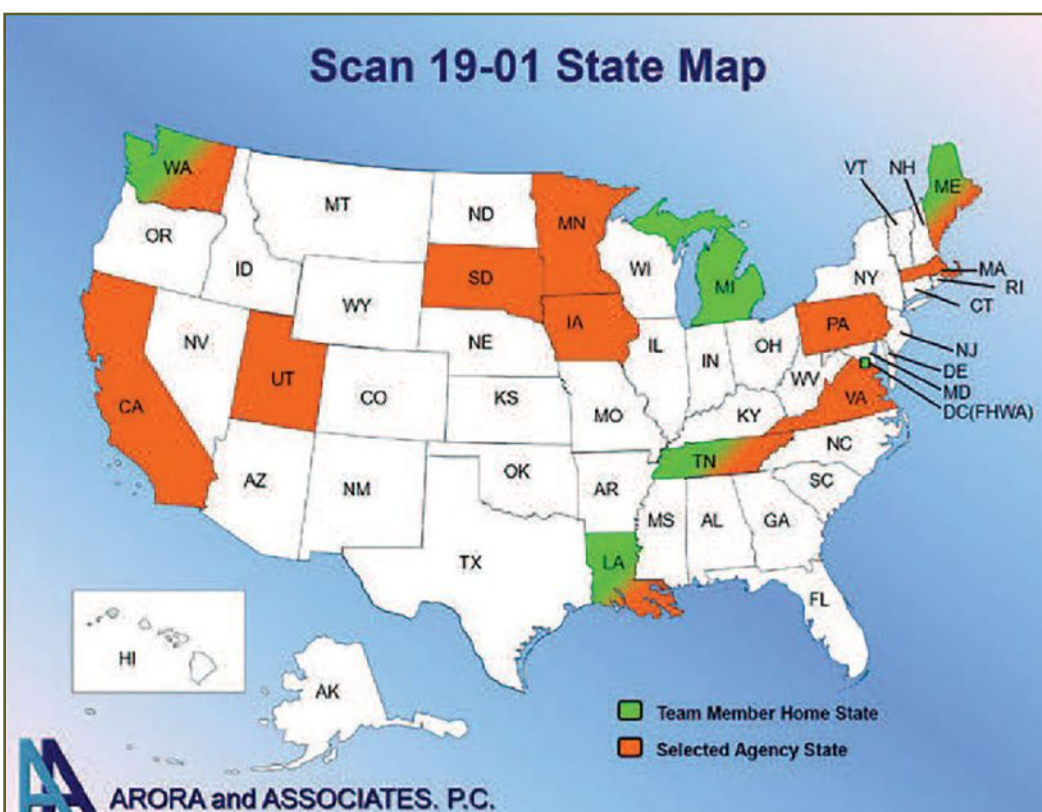

Figure 1. Map showing states with members on the scan team and states selected to participate in Scan 19-01. Source: DeRuyver et al., 2020.

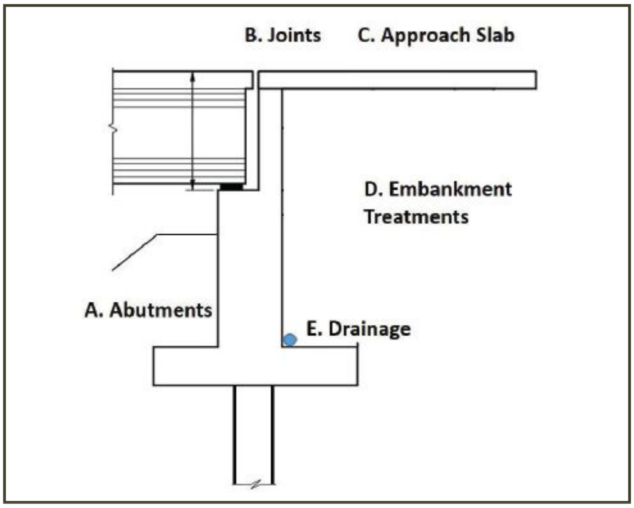

Figure 2. Fourteen departments of transportation shared practices and details related to five bridge components (labeled A–E in the diagram) in hopes of finding a solution to the "bump at the end of the bridge." Although no single remedy was found, *Leading Practices for Detailing Bridge Ends and Approach Pavements to Limit Distress and Deterioration*[1] provides notable findings, including lessons learned.

As can be seen from the questions, the scan addresses more than design details and practices. Construction, repair, inspection, and maintenance are also considered. The complete list of questions is located in an appendix of the report, and the responses are incorporated into the report.

In November 2019, the scan team and representatives from 12 of the 14 state agencies met to share details and lessons learned in bridge end design. Their primary aim was to share what has worked, what has not worked, and why. Each state was given two hours to present details used in their state and answer questions.

Following the presentations, the scan team concluded that given the varying conditions in each state, there is no one-size-fits-all solution to resolving the "bump at the end of the bridge." However, most of the participating states agreed that eliminating joints from the bridge deck and controlling and designing for effective drainage are crucial strategies for structure longevity. From the presentations and the abundance of information gathered, the scan team assembled findings, termed "notable practices of interest." The following are examples of these practices:

- Flowcharts or other tools for selecting appropriate abutment types
- Sample calculations for design of integral or semi-integral abutments
- Design and support of approach slabs
- Compaction methods and requirements for embankments

The scan also included sharing of state-sponsored research, information on cost equivalency analysis, and sustainability practices.

Summary

The Scan 19-01 report[1] is an impressive document that presents various states' practices and details used at the ends of bridges to achieve a jointless structure while minimizing structural distress, reducing maintenance and repair costs, and improving performance. The report is organized and well documented with state-specific details, practices, and lessons learned.

An important aspect of any scan is to disseminate the information collected. Jason DeRuyver, chair of the scan team, gave a presentation on the findings of Scan 19-01 at the AASHTO TSP2 Western/Midwest Bridge Preservation Partnership meeting in Phoenix, Ariz., in December 2021. It can be found on YouTube (https://www.youtube.com/watch?v=KaQl3GOdZno).

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Silica Fume's Contribution to Sustainability

by Eckart Bühler, Norchem-Ferroglobe

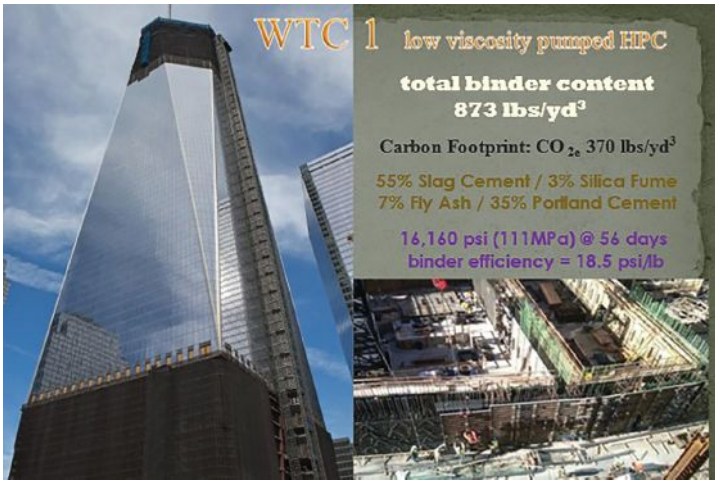
Sustainability, resilience, carbon footprint, and life-cycle analysis are becoming keywords in everyday conversation, whether related to energy consumption, food supply, global warming, or human expansion in general. These also extend to concrete, the most commonly used building material on the globe. Ordinary portland cement (OPC), historically the key ingredient in concrete, comes with a relatively high carbon footprint of approximately 1 ton of carbon dioxide (CO_2) per ton of cement produced; thus significant pollution status has been assigned to concrete.[1] Industrial processes and fine-tuning of cement production with alternative ingredients, additives, and energy supplies have been able to lower concrete's carbon footprint by up to 20%, and additional tools are available to go even further.

As stated in the article "Road Map to Carbon Neutrality for Concrete Materials" in the Winter 2022 issue of *ASPIRE*®, "the single greatest opportunity for CO_2 reductions in concrete as a material remains with mixture optimization. Concrete mixtures can be optimized by increasing the use of SCMs [supplementary cementitious materials]."[2] There are various SCMs, including three that the U.S. Environmental Protection Agency identified as recovered mineral components (RMCs) in 2008.[3] These three RMCs—slag cement, fly ash, and silica fume—are designated preconsumer waste materials whose application in concrete removes materials from the national waste stream. They have been used as alternatives to cement in concrete for decades, but traditionally not for the purpose of carbon-footprint reduction.

Slag cement and fly ash can be used in place of OPC at large replacement percentages (at roughly a 1:1 ratio), significantly reducing the OPC content in a concrete mixture. The contributions of slag cement and fly ash to the durability and life-cycle extension of concrete structures have also been noted.

Silica fume is included in much smaller percentages than slag cement or fly ash, but it has a powerful synergistic effect that allows concrete to achieve very high strengths as well as durability characteristics that can facilitate 100-year or more life-cycle performance of structural concrete. From a purely compressive strength perspective, each pound of silica fume can compensate for 3 to 4 pounds of OPC. Silica fume is also uniquely positioned as a borderline nanomaterial, making it an important tool for optimizing concrete mixture proportions by enabling ternary and quaternary binder formulations that provide desirable mechanics for ideal rheology of complex concrete mixtures.

Higher concrete performance requirements are well known to the bridge-building industry, where they are routinely employed. The 2008–2009 reconstruction of the collapsed Interstate 35W bridge in Minneapolis, Minn., is an example where combinations of these three SCMs/RMCs were ingeniously employed in ternary blended concrete mixture proportions to achieve not only a fast-track rebuild in a 14-month span but also, and more importantly, a 100-year design life for the replacement structure with a reduced carbon footprint.[4] The 4000-psi concrete designed for the piers employed a mere 15% of OPC, whereas silica fume application in the superstructure concrete achieved compressive strengths greater than 8000 psi and a very low permeability rating; the resulting increased concrete impedance will inhibit corrosion of the embedded steel reinforcement.



One World Trade Center in New York, N.Y., used a sustainable concrete mixture with an exceptionally high binder efficiency. Figure: Norchem-Ferroglobe.

On the 2008–2013 One World Trade Center reconstruction project in New York, N.Y., a quaternary blended concrete mixture reduced the OPC volume to only 36% of the total binder content. The concrete had a compressive strength greater than 16,000 psi and a carbon footprint as low as a conventional 4000-psi concrete mixture made with straight OPC. Silica fume's main functions in this project scenario were to retain reasonable concrete setting times for timely formwork removal, even with large slag cement and fly ash replacements; achieve very high ultimate strength; and impart favorable rheology to the fresh concrete. The latter allowed single-stage pumping to the full height (1368 ft) of the structure and placement of self-consolidating concrete into densely reinforced areas.

Specifically at low doses—less than 4% by volume of total binder—silica fume introduces hundreds of thousands of minute spherical particles into the concrete, creating a ball-bearing effect that reduces concrete viscosity and negates its own water demand. This effect is more evident at higher percentage inclusions, where the increased water demand can be offset with a high-range water-reducing admixture (HRWRA). Modern HRWRAs can facilitate high workability in concrete, even at extremely low water–cementitious material (*w/cm*) ratios. This allows the total binder contents to be kept to a minimum, which results in a lower carbon footprint.

The bridge and transportation industry seems to be ahead of others in implementing sustainable concrete mixture proportions for achieving long life. The original purpose of these mixtures, however, was to extend the service life for concrete structures that are exposed to more wear and tear and harsher environmental conditions than most other concrete applications. Within the transportation sector, there is room for employing even higher compressive strengths to construct even more slender structures that also excel in long-term durability, leading to excellent sustainability stewardship by using fewer construction materials as well as securing a long structural life.

Table 1 compares three conventional concrete mixture designs with three high-performance concrete mixtures used in projects completed more than two decades ago.[1,5,6] The data demonstrate the advantages of designing for high-strength concrete, which include enabling longer spans and more slender superstructures while using the smallest feasible volume of concrete, as well as extending the service life by requiring less maintenance and delaying replacement work. The table also shows that concrete made with silica fume, slag cement, and fly ash, or any combination thereof, can reduce the carbon footprint of concrete to an average of one-tenth that of conventional mixtures when measured in terms of compressive strength attained and accounting for the expected service life of the structure.

For the projects listed in Table 1, the high-performance concrete mixtures used HRWRAs. Because the binder portions of most concrete represent 90% to 95% of its carbon footprint, only the contributions of those materials are considered in the CO_2 equivalent (CO_2e) calculations. The life-cycle analysis used a 1.5-in. concrete cover over reinforcing bars for a severe exposure in a southern climate for each of the six concrete mixtures described.[6]

High-performance concrete does not translate to a concrete with a high carbon footprint, although a high cement factor is typically assumed. When accounting for in-service performance, structural life cycle, and the original materials used, high-performance concrete may have a much lower carbon footprint than a conventional 4000-psi design-strength concrete. Incorporating SCMs in concrete mixtures is key in achieving reduced carbon footprints, and the addition of silica fume is particularly critical to maximize concrete resistance to the ingress of deleterious substances that shorten concrete service life. High compressive and flexural strengths, as well as

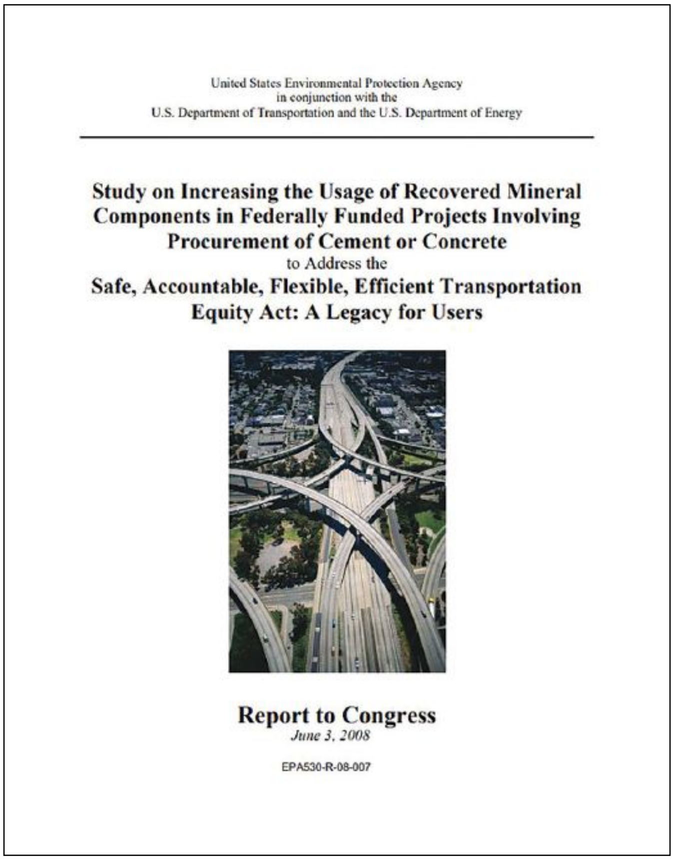
Table 1. Comparison of the carbon footprint of three conventional concrete mixtures with three high-performance concrete mixtures

	Cementitious materials			*w/cm*	CO_2e (binder material only), lb/yd³	Concrete compressive strength,* psi	CO_2e per 1000-psi compressive strength, lb	Years to initiation of corrosion	CO_2e per year based on initiation of corrosion, per 1000-psi compressive strength, lb	
	Type	Amount	% of total *cm*						Mixture or project	Average for group
Examples of conventional mixtures	**Conventional concrete mixture Design 1**			0.50	375	4500	83	10	8.3	5.97
	OPC	500 lb/yd³	100%							
	Total *cm*	500 lb/yd³								
	Conventional concrete mixture Design 2			0.50	305	4500	68	12	5.7	
	OPC	390 lb/yd³	70%							
	FA	170 lb/yd³	30%							
	Total *cm*	560 lb/yd³								
	Conventional concrete mixture Design 3			0.50	231	4500	51	13	3.9	
	OPC	265 lb/yd³	50%							
	SC	265 lb/yd³	50%							
	Total *cm*	530 lb/yd³								
High-performance concrete projects	**Millennium Tower, Miami, Fla.**			0.29	395	11,700	34	62	0.5	0.57
	OPC	456 lb/yd³	48%							
	SC	446 lb/yd³	47%							
	SF	48 lb/yd³	5%							
	Total *cm*	950 lb/yd³								
	Radioactive Waste Storage Facility, Hanford, Wash.			0.37	305	6300	48	62	0.8	
	OPC	391 lb/yd³	65%							
	FA	150 lb/yd³	25%							
	SF	60 lb/yd³	10%							
	Total *cm*	601 lb/yd³								
	Solid Waste Authority, Palm Beach County, Fla.			0.34	446	10,300	43	100+	0.4	
	OPC	578 lb/yd³	68%							
	FA	127 lb/yd³	15%							
	SF	141 lb/yd³	17%							
	Total *cm*	846 lb/yd³								

Source: Norchem-Ferroglobe.

*The concrete compressive strength is the 28-day design value for conventional concrete mixture designs and the actual 28-day value from test specimens for the high-performance concrete projects.

Note: *cm* = cementitious materials; CO_2e = carbon dioxide equivalent; FA = fly ash; OPC = ordinary portland cement; SC = slag cement; SF = silica fume; *w/cm* = water–cementitious materials ratio.


United States Environmental Protection Agency
in conjunction with the
U.S. Department of Transportation and the U.S. Department of Energy

Study on Increasing the Usage of Recovered Mineral Components in Federally Funded Projects Involving Procurement of Cement or Concrete
to Address the
Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

Report to Congress
June 3, 2008

EPA530-R-08-007

high modulus of elasticity, can optimize designs and reduce the volume of concrete required, thus reducing the use of non-renewable resources.

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Central Texas Regional Mobility Authority: Creating a Regional Transportation Network

by Dee Anne Vickery, Central Texas Regional Mobile Authority

One of three pedestrian bridges crossing the 183 Toll, an 8-mile toll road along U.S. Route 183 in east Austin, Texas. A notable feature of the bridge is the inverted triangle bents, a design that is unique to the region. The bents support a concrete beam superstructure with a decorative steel railing and facade. These bents required significant reinforcing steel in the bottom "knuckle" of the bents and unique formwork. All Photos and Figures: Central Texas Regional Mobility Authority.

The Central Texas Regional Mobility Authority is an independent government agency focused on making the connections that improve mobility and help central Texans get to where they need to go. The agency's mission to use innovative transportation solutions to drive those connections and enhance quality of life for the region is apparent across all Mobility Authority facilities. But it's perhaps best illustrated, both figuratively and literally, by the many bridge structures built and operated by the agency.

Since its inception in 2002, the Mobility Authority has brought to life many projects in the Austin area, including the 183A Toll, 290 Toll, 71 Toll Lane, 45SW Toll, and MoPac Express Lane. More recently, the agency opened the 183 Toll and broke ground on two vital connections north of downtown Austin with the 183 North mobility project and 183A Phase III.

A few distinctive features of Mobility Authority projects are that they include improvements to the existing adjacent general purpose (nontoll) lanes, they encourage multimodal transportation by building shared-use paths along most of their roadways, and they use congestion management tools such as variably priced express lanes like the MoPac Express Lane.

The completion of the 290/130 Flyover Project in February 2021 added three new flyover bridges at the intersection of 290 Toll and State Highway 130. These structures provide vital direct connections between two major facilities east of downtown Austin, effectively reducing congestion on the frontage road intersection and increasing connectivity

Bear Creek Bridge, which was built as a part of the environmentally sensitive 45SW Toll project, mitigated impacts to Bear Creek. The project's shared-use path features educational signage and a corresponding augmented-reality mobile app to educate the community and foster environmental stewardship.

Crews simultaneously constructed piers for three new flyovers at the intersection of 290 Toll and State Highway 130.

Regional map showing Central Texas Regional Mobility Authority roadway system.

for Williamson County and northeast Travis County.

The new flyover bridges have many concrete components, including 2135 ft of 96-in.-deep prestressed concrete girders, 762 ft of 108-in.-deep prestressed concrete girders, and 12,993 ft of Tx54 prestressed concrete girders. The direct connectors also feature bridges with supershafts (drilled shafts with diameters of more than 90 in.). Temperature sensors in the supershafts were used to monitor and assess the proper curing of the concrete during construction.

The contractor constructed all three flyovers at once, which required diligent traffic-control coordination. Templates for the monolithic drilled shafts were used to assist with their alignment during drilling and concrete placement. Additionally, the Mobility Authority's contractor prioritized finishing during placement of the continuously reinforced concrete pavements to ensure ride-quality requirements were met, as some of the early placements required grinding to achieve international roughness index ride-quality requirements. The scope of this project included:

- 11,000 ft of drilled shafts
- 18,000 yd^3 of concrete structures
- 60,000 ft of concrete beams
- 66,500 ft^2 of mechanically stabilized earth retaining walls
- 97,000 yd^3 of embankment
- 594,000 ft^2 of bridge deck

The 183 Toll—an 8-mile toll road along U.S. Route 183 in east Austin that serves as an alternative to the highly congested Interstate 35—features 58 delta portal bents. These signature bridge bents are shaped as inverted triangles, a design that is unique to the region. They required significant reinforcing steel in the bottom "knuckle" of the bents and unique formwork.

Bear Creek Bridge was built as a part of the 45SW project, which crosses through the environmentally sensitive Edwards Aquifer recharge zone. The bridge itself mitigates environmental impacts to Bear Creek. Also, to educate the community and foster environmental stewardship, the Mobility Authority developed an augmented-reality app and installed corresponding educational signs along the project's shared-use path. The app educates users about specific features of the Texas hill country such as native plants and animals, how the Edwards Aquifer functions, and more.

The work of the Mobility Authority continues, and bridges feature in the agency's active construction projects. The 183 North mobility project includes 13 bridges, 11 of which are widenings, including a drop-in girder span. The 183A Phase III project will involve 17 bridges made up of 191 columns, 517 beams, and 97 spans.

The Mobility Authority's current (and future) roadway system is designed to deliver faster, safer, and more reliable drive times throughout central Texas, and its bridges are integral to this mission.

Dee Anne Vickery is the chief of staff for the Central Texas Regional Mobility Authority in Austin.

Three new flyover bridges at the intersection of 290 Toll and State Highway 130 provide vital direct connections between two major facilities east of downtown Austin, Texas. The new bridges use many concrete components, including 2135 ft of 96-in.-deep prestressed concrete girders, 762 ft of 108-in.-deep prestressed concrete girders, and 12,993 ft of Tx54 prestressed concrete girders.

Purple Epoxy-Coated Reinforcement: Q & A

by Peter Fosnough, Epoxy Interest Group of the Concrete Reinforcing Steel Institute

After I penned "Purple Epoxy-Coated Reinforcement: Does Color Make a Difference?" for the Spring 2022 issue of *ASPIRE*®, several questions have been raised. I will try to succinctly address them.

Why should I specify one over the other? Do I specify either, or both?

Generally, there is no reason to specify one epoxy-coated reinforcement standard over the other standard. Both standards, ASTM A775[1] (green) and ASTM A934[2] (purple), equally protect the steel from corrosion. In fact, I recommend specifying both to ensure that local capabilities for sourcing are taken into account. However, when in doubt, always specify A775, as it is the most prevalent and readily available material in North America.

Is there any other reason (project, application, etc.) to use one over the other?

Because of the constraints in the coating operation, the finished size of the fabricated reinforcement item may restrict the use of A934. If the smallest dimension of an item exceeds the capability of an A934 (purple) coater, the material will have to be A775 (green) and then fabricated after coating. For example, a large column on a bridge project required a 12-ft round tie for confinement and the engineer wanted the entire tie to be a single, continuous piece of reinforcement and did not want to use a coupler. The largest diameter the local coater could accommodate using A934 was 10 ft. By specifying A775, the material was coated in approximately 40-ft lengths and then fabricated into a 12-ft round tie with hooks.

How do I find out which fabricators (green or purple) are in my area, or does it matter?

The Concrete Reinforcing Steel Institute (CRSI) maintains a roster of CRSI-certified plants listed by state, which identifies facilities with straight bar lines and those with custom lines.[3] Straight bar lines typically focus on A775 (green) coating. Custom lines typically focus on A934 (purple) coating, but can do both.

Can I "mix" purple bar and green bar on the same project or structural element?

Both purple and green reinforcing bars can be used on the same project or structural elements. However, it is not typical because fabricators of epoxy-coated reinforcing steel usually only produce one type of bar, purple or green.

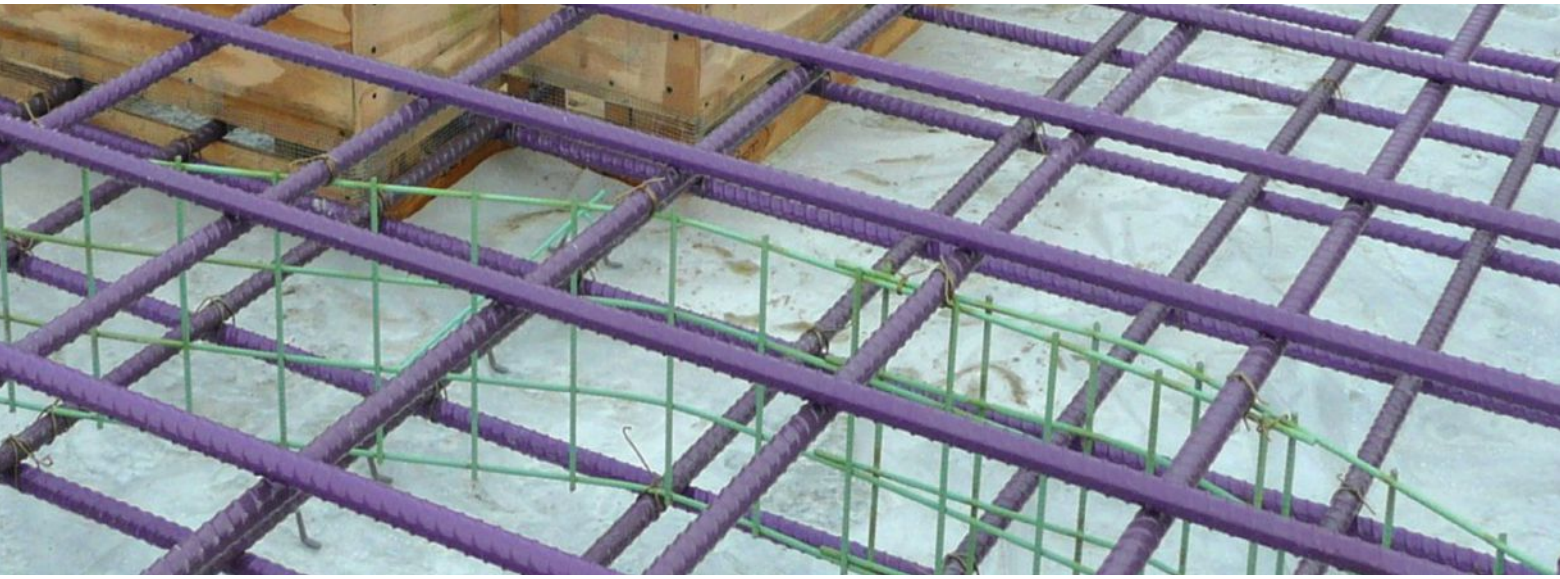
What about tie wire?

Coated steel tie wire should be used when tying epoxy-coated steel reinforcing bars regardless of the coating color. On small projects, it is not uncommon to use plastic cable ties. Bare metal or abrasive material should not be used or come into contact with the epoxy-coated reinforcing steel.

What about repair?

All bare steel or damaged areas should be repaired to ensure maximum

Photo: Lane Enterprises



protection from corrosion. Regardless of whether the coated material is A775 or A934, all patching material should be specified to meet ASTM A775 Annex A2 requirements. When patching material does not meet these requirements, the corrosion protection of the steel is compromised. When specifying patching material, I recommend that the following language be used: "Patching material shall meet all of the testing performance requirements in Annex A2 of the ASTM A775 specification."

How well do these reinforcing bars perform in service?

As I mentioned in the previous article, through more than 50 years of use and refinement, epoxy-coated reinforcing steel produced to today's A775 or A934 standards far exceeds the performance of the product introduced in 1973. A recent University of Kansas study states that "a 100-year design life is possible even in the presence of minor damage."[4]

What happens if someone bends a purple bar in the field? What are the ramifications?

Because A934 (purple) is not designed to be modified in the field, attempts to bend it will likely cause the coating to fracture and separate from the steel. If damage to the coating occurs, repair (using approved patching material) will be required.

I hope these responses have clarified any lingering questions. Should you have any additional inquiries, feel free to contact me at pfosnough@epoxy.crsi.org.

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1. ASTM International. 2019. *Standard Specification for Epoxy-Coated Steel Reinforcing Bars*. ASTM A775/A775M-19. West Conshohocken, PA: ASTM International.
2. ASTM International. 2019. *Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars*. ASTM A934/A934M-19. West Conshohocken, PA: ASTM International.
3. Concrete Reinforcing Steel Institute (CRSI). "CRSI Epoxy Coating Plant Certification Program." https://www.crsi.org/index.cfm/certification/plant.
4. O'Reilly, M. 2022. *Effect of Damaged Area on Service Life of Epoxy-Coated Reinforcement* SL Report 22-2. Lawrence, KS: The University of Kansas Center for Research Inc. https://iri.ku.edu/sites/iri/files/files/pdfs/SL%20Report%2022-1.pdf.

Peter Fosnough is the managing director of the Epoxy Interest Group of the Concrete Reinforcing Steel Institute in Schaumburg, Ill.

Participants in the Concrete Bridge Engineering Institute (CBEI) courses will have opportunities to see concrete bridge elements up close. Post-tensioning anchorage details, pretensioned strands, duct placement, and a composite deck are visible in this precast, prestressed concrete post-tensioned spliced girder research specimen. Photo: CBEI.

CBEI SERIES

Building the Concrete Bridge Engineering Institute

by Dr. Oguzhan Bayrak and Gregory Hunsicker,
Concrete Bridge Engineering Institute

The Summer 2022 issue of *ASPIRE*® introduced the Concrete Bridge Engineering Institute (CBEI) and provided an overview of the ongoing activities of the institute and the needs that inspired its creation. Interest has been tremendous, and work to get the institute's programs up and running is continuing. This article continues the introduction by discussing the request for funding for CBEI through the Transportation Pooled Fund (TPF) Program and exploring further the key components of CBEI.

Transportation Pooled Fund

The TPF Program was first established in 1977 as a program administered by the Federal Highway Administration (FHWA) in coordination with state departments of transportation (DOTs). It has been in its current format for more than 20 years and has produced many valuable deliverables through partnerships between state DOTs and other partner agencies, including the FHWA, colleges and universities, private companies, and other organizations and agencies.

CBEI was advertised as a TPF study in May 2022.[1] As noted in the TPF *Procedures Manual*, "A TPF study is intended to address a new area of planning, research or technology transfer or provide information that will complement or advance those areas."[2] CBEI seeks to address several of those goals. Some of the objectives established for this study are:

> *to implement specific programs within CBEI that address national workforce training needs through research, development, and technology transfer activities. The technology transfer through training programs will draw on the latest technologies and provide an innovative approach by utilizing a hands-on intensive curriculum. The training programs will draw from the best, and most current, state of the art methods. CBEI will serve to continually gather emerging or underutilized technologies … and provide research, development, and technology transfer activities in partnership with the originators of the technology. This will result in training curricula and technology transfer documents for the concrete bridge workforce.…*
>
> *The objective of this pooled fund is for CBEI to become a national resource for innovative workforce development programs and implementation of new technologies in the field of concrete bridges.*[1]

The lead organization for this TPF study is the Texas Department of Transportation, and the initial effort is proposed as a four-year study. FHWA has committed to the study as a partner agency, and other agencies are expected to join.

Participating members in the study will serve a critical role in providing direction and feedback for the CBEI programs through the TPF study's technical advisory committee. Benefits to participating members include training for employees, the ability to call on institute experts for technical questions, custom workshops, involvement in research and development efforts, and opportunites to set the direction for those efforts. Training courses will be available not only to TPF members but also to participants throughout the concrete bridge community. The institute also serves as a hub for information sharing among its members and the concrete bridge industry.

Program Development

Three specific needs ("pillars of learning") will be addressed by the TPF study. A program will be developed for each of the three initial topics, all of which will include both classroom and hands-on training. The infrastructure for the programs, including the site development, hands-on specimens, and curricula, will be developed during the first three years, and the individual programs will be made available as the relevant infrastructure is completed.

Concrete Materials for Bridges Program

The first program scheduled to be made available is the Concrete Materials for

The Concrete Bridge Engineering Institute (CBEI) has a collection of concrete bridge components that will be used to help participants compare theoretical behavior to actual test results, and predict and evaluate cracks in concrete. Photo: CBEI.

Concrete blocks that will be used in the Concrete Materials for Bridges Program. The blocks have different confinement and reinforcement details and show the effects of alkali-silica reaction. Photo: Concrete Bridge Engineering Institute.

Bridges Program, which is designed to provide guidance on the proper selection and use of constituent materials to improve the service life of concrete bridges and the sustainability of concrete construction. This program will also provide hands-on examples of what happens when these issues are not considered. Topics covered will include considerations for constituent materials, avoiding issues such as alkali-silica reaction and delayed ettringite formation, evaluating cracks in concrete, understanding failure mechanisms, troubleshooting, and corrosion of reinforcement. The program will also cover sustainability and how evolving practices in the industry affect some of these considerations. Other topics such as mass concrete will also be introduced. While the focus will be on best practices and strategies to ensure proper initial construction, some of the program will be dedicated to evaluating and extending the life span of existing infrastructure. Many of these efforts will be led by Dr. Kevin Folliard and Dr. Anca Ferche of CBEI, in collaboration with a network of subject matter experts (SMEs) from around the United States.

Bridge Deck Construction Inspection Program

The second program scheduled to be made available is the Bridge Deck Construction Inspection Program, which will use full-scale, hands-on components to train participants on the proper initial construction of concrete bridge decks. The initial program is intended primarily for new construction inspectors and engineers; however, it is anticipated that the program will be expanded to train installation crews and supervisors. The Bridge Deck Construction Inspection Program will include techniques using technologies that are prevalent across the United States, as well as emerging technologies, where appropriate. The deck construction technologies that will be covered include partial- and full-depth precast concrete deck panels, stay-in-place metal forms, plywood forms, and prestressed decks, among others. The program will implement information from such sources as FHWA's recently published *State-of-the-Practice Report: Partial-Depth Precast Concrete Deck Panels*.[3]

The curriculum will look at problems alongside correct installations in full-scale bridge components. The goal is to illustrate the best methods and details, and to provide meaningful examples of things to watch out for and avoid, from the initial design through field installation. Topics to be addressed include placing reinforcement and ensuring proper cover; performing a dry run; screed setup and operation; concrete placement, curing, and finishing; joints; overhang brackets; prestressing details; precast concrete deck component evaluation; and other details. Ensuring the performance of bridge decks is important due to their critical role in the overall structure, their exposure to harsh environments (including deicing chemicals), and their large surface areas. Therefore, proper initial bridge deck construction, taking into account the best available technology and details, is crucial. Once again, this effort will be led by the network of SMEs participating in CBEI.

Post-Tensioning Academy

The third program will be the Post-Tensioning Academy, which will provide hands-on training for engineers, field installers, and inspectors, as well as perform tests to verify promising post-tensioning technologies with associated research and development efforts. This program seeks to build on the successful training already offered by both the Post-Tensioning Institute and the American Segmental Bridge Institute, and provide training on post-tensioning installation and inspection through stations dedicated to the different phases of construction. For example, participants will perform the field functions associated with duct and anchorage installation, strand installation, stressing, and grouting with interactive hands-on modules. Within those areas, trainees will focus on the functions they typically perform in the field. For example, inspectors will focus on inspection-related tasks, and installers will concentrate on installation-related tasks. Best practices, understanding specification requirements, and the potential repercussions when steps are not carried out properly will be emphasized through hands-on examples, such as reconciling a failed pre-grouting air test or recording tensioning elongations and reconciling discrepancies. Other stations will include grout testing, proper pourback installation for blockouts and grout vent recesses, and post-grout inspection. Another important aspect of the curriculum will be training on the initial approval of post-tensioning systems and subsequent verification that the approved systems are being used on the project.

While training in existing technologies is important, there is also a need to support the successful implementation of emerging and underused technologies. This includes working with stakeholders, developers, and SMEs for

Stressing strands in a post-tensioning tendon for a demonstration specimen at the Ferguson Structural Engineering Laboratory (FSEL). Concrete Bridge Engineering Institute (CBEI) courses will include full-scale specimens for hands-on demonstrations of post-tensioning operations, including stressing. Photo: CBEI/FSEL.

various technologies. As technologies addressing such topics as electrically isolated tendons, monitorable tendons, replaceable tendons, improved grout monitoring/testing, and others are introduced, CBEI plans to encourage their implementation by leveraging contributions of its national network of SMEs.

Conclusion

This is the second in a series of articles about CBEI and its impact on the concrete bridge industry. Articles in upcoming issues of *ASPIRE* will explore the technical programs in greater detail as well as CBEI's collaboration with the National Concrete Bridge Council and its members.

For more information about CBEI, please visit: https://www.cbei.engr.utexas.edu.

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1. Transportation Pooled Fund. 2022. "Solicitation Details: Concrete Bridge Engineering Institute (CBEI)." https://www.pooledfund.org/Details/Solicitation/1580.
2. Federal Highway Administration (FHWA). 2022. *Transportation Pooled Fund Procedures Manual.* Washington, DC: FHWA. https://pooledfund.org//StaticDocuments/Reports/TPF%20Procedures%20Manual%20July%202022.pdf.
3. McDonagh, M., A. Foden, and A. Beyer. 2022. *State-of-the-Practice Report: Partial-Depth Precast Concrete Deck Panels.* FHWA-HIF-22-031. Washington, DC: FHWA. https://www.fhwa.dot.gov/bridge/concrete/hif22031.pdf.

Dr. Oguzhan Bayrak is a professor at the University of Texas at Austin and director of the Concrete Bridge Engineering Institute. Gregory Hunsicker is a research engineer at the University of Texas at Austin and deputy director of the Concrete Bridge Engineering Institute.

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HELSER INDUSTRIES helser.com	**Helser Industries** designs and manufactures steel forms for producing precast and prestressed concrete components for numerous commercial applications.	10750 SW Tualatin Road PO Box 1569 Tualatin, OR 97062 503.692.6909

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CONCRETE CONNECTIONS

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

IN THIS ISSUE

https://www.mobilityauthority.com
The Central Texas Regional Mobility Authority is featured in the article on page 49. This is a link to the authority's website, which provides maps and fact sheets on current and future projects in the region.

https://usdot.zoomgov.com/rec/play/3HIaTbmKIjupNOA9aqDpvEA7OC6RX_kJ8e1TxkinXdB8XK9ouFluRc5qeH5wEzFI3gL2ysToeqaGWkXr.cc31Ges3rZDy-NOK?continueMode=true
This is a link to a webinar presented by the Federal Highway Administration on August 2, 2022, to review the recent changes to the Buy America requirements, which were discussed in the Perspective article on page 10. The passcode to access the webinar recording is *DiG2s4S

https://abc-utc.fiu.edu/mc-events/north-carolinas-rodanthe-jug-handle-bridge-precast-bridge-elements-and-innovative-construction-approach/?mc_id=729
The Rodanthe "Jug Handle" on North Carolina's Outer Banks is featured in the Project article on page 26. This is a link to a webinar from Florida International University's Accelerated Bridge Construction Center about the innovative construction techniques used on that project.

https://www.flatironcorp.com/project/n-c-12-rodanthe-bridge
Flatiron was the contractor on the Rodanthe "Jug Handle" Bridge on North Carolina's Outer Banks, which is the focus of the Project article on page 26. This is a link to a project summary on Flatiron's website with details and photos of the site and construction.

https://www.txdot.gov/inside-txdot/get-involved/about/hearings-meetings/amarillo/080619.html
The Texas Department of Transportation (TxDOT) held a preconstruction open house about the U.S. Route 83 and State Highway 15 bridge replacements project. This link is to a web page where slides of the project presentation, which shows the original design concept. After letting, the contractor and precaster submitted an alternative design that was accepted by TxDOT. This project is featured in the Project article on page 18 and in the Creative Concrete Construction article on page 40.

https://lsc-pagepro.mydigitalpublication.com/publication/?m=61068&i=741590&p=20&pre=1&ver=html5
The Concrete Bridge Technology article on page 38 presents engineering details of the rehabilitation of the Lake Tillery Bridge. This is a link to a Project article about construction aspects of the bridge that appeared in the Spring 2022 issue.

https://www.youtube.com/watch?v=Ae5PLpZZW48
The reconstruction of the Lake Tillery Bridge superstructure is the focus of the Concrete Bridge Technology article on page 38. Before the construction of this bridge in 1927, there was another one: Swift Island Bridge, an open-spandrel reinforced concrete arch bridge built in 1922. After completion of the Lake Tillery Bridge, the older bridge was used for load testing while it was still intact. This is a link to a video documenting the testing and demolition of Swift Island Bridge.

https://onlinepubs.trb.org/Onlinepubs/nchrp/docs/SCAN19-01rev3.pdf
The Creative Concrete Construction article on page 44 highlights the process and findings of the National Cooperative Highway Research Program's Scan 19-01. The scan addressed "the bump at the end of the bridge." Most of the 12 participating states agreed that eliminating joints from the bridge deck and controlling and designing for effective drainage are crucial to structure longevity. This is a link to download the Scan 19-01 report.

https://nationalconcretebridge.org
The National Concrete Bridge Council (NCBC), composed of trade associations serving the concrete bridge industry, is the focus of the Perspective article on page 14. This is a link to the NCBC website.

http://concretebridgeviews.com
This is a link to an archive of all issues of the *HPC Bridge Views* and the *Concrete Bridge Views* newsletters, which were jointly sponsored by FHWA and NCBC and are mentioned in the Perspective article about NCBC on page 14.

https://www.fhwa.dot.gov/bridge/nbis2022.cfm
The Federal Highway Administration article on page 63 outlines the history of the National Bridge Inspection Standards and recent changes made to ensure national uniformity for inspections and evaluations. This link provides access to several resources related to those recent changes.

OTHER INFORMATION

https://www.asbi-assoc.org/index.cfm/events/MonthlyWebinars
This link accesses the American Segmental Bridge Institute's (ASBI's) archived webinars. The Design and Construction of Concrete Segmental Bridges for Rail is the subject of one of the webinars. Also available for download from the Publications section of the ASBI website is the recently published *Guidelines for Design and Construction of Concrete Segmental Bridges for Rail.*

https://www.penndot.pa.gov/pages/all-news-details.aspx?newsid=974
This is a link to a news release announcing that the Pennsylvania State Transportation Commission has updated its 12-Year Program. The new plan anticipates that $84 billion will be available over the next 12 years for transportation infrastructure improvements.

Engaging Industry to Enhance Student Learning

by Dr. Brandon Ross, Clemson University

I'm coming up on my tenth anniversary at Clemson University. It has been a decade filled with many outstanding students whose curiosity and eagerness have kept me motivated and given me confidence in the future of our industry. Over the years, I've observed that my students are highly motivated to connect classroom learning with real-world projects and examples. For this reason, I'm deliberate about bringing the real world into every class that I teach, particularly by engaging industry professionals. This is especially relevant for my Prestressed Concrete Design and Highway Bridge Design classes. At this milestone in my career, I want to share some successful strategies for engaging the industry to enhance student learning.

- **Field trips and plant visits**. Industry partners have hosted my students at construction sites, in-service bridges, and precast concrete plants (**Fig. 1**). It is amazing to watch my students light up when they see that concrete and reinforcing bars aren't just abstract concepts which I tell them about in class! There is no substitute for in-person observation.
- **Professional writing samples**. Students often tell me that they decided to pursue engineering because they like math and science but not writing. Whenever I hear this, I promptly counter by telling the students that written communication is essential to engineering practice. To introduce students to professional writing, I give them examples of site-visit reports and request-for-information (RFI) memos. The samples are provided by practicing engineers, with any sensitive information redacted. I assign the students to write reports and RFIs using the sample documents for guidance. These assignments pair nicely with field trips.
- **Structural connection details**. University curricula tend to focus primarily on component design and less on how components come together to transfer forces and moments. Recognizing this gap, I created a slide template for a "connection of the day" (**Fig. 2**) and invited practicing engineers to use the template to describe structural connections. Some connections are unique and complex; others are common and simple. Each week in class, I share one or two connections. I aim to introduce students to different types of connections and highlight the importance of detailing in structural engineering.
- **Reverse interviews**. Typically, industry employers interview students who are seeking employment. I reversed these roles and gave my students an assignment to interview practicing engineers. The students asked about the day-to-day work of an engineer and the importance of professional licensure.

Figure 1. Dr. Ross and students visiting an apartment complex construction site. Through field trips and plant visits, students connect classroom learning with real-world examples. Photo: Clemson University.

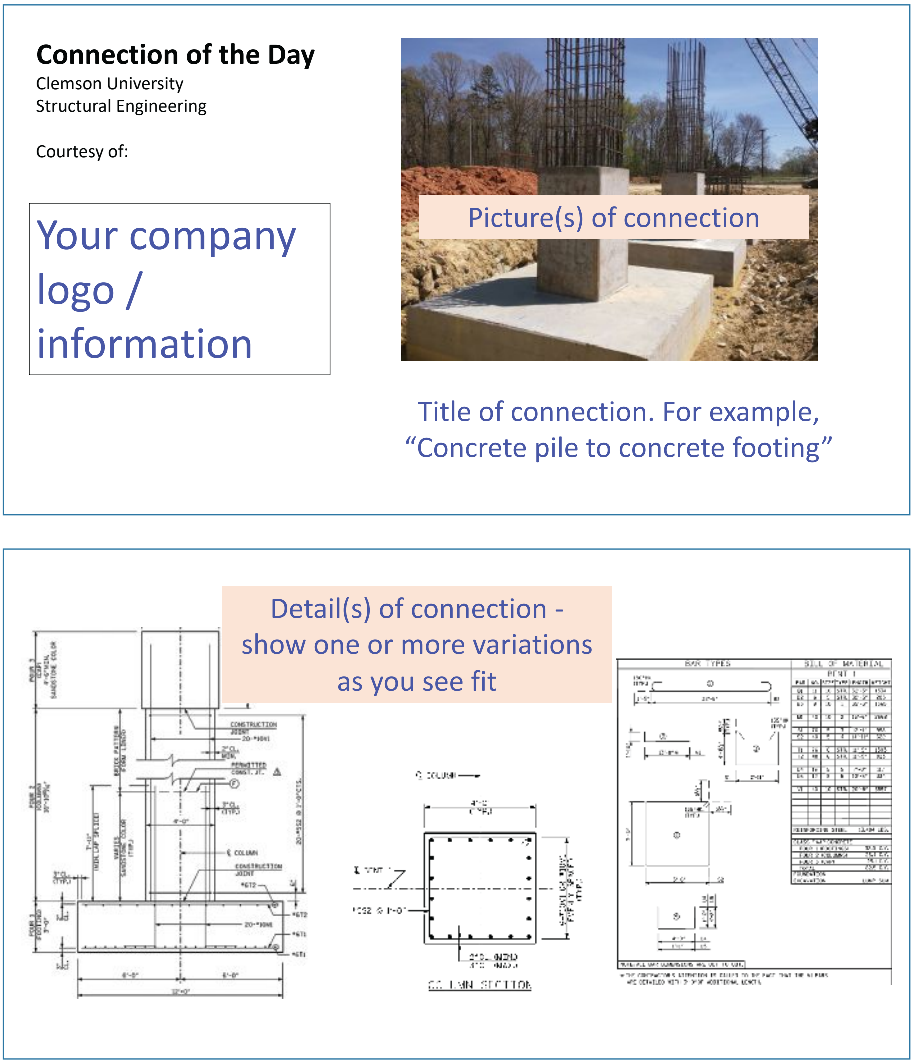

Figure 2. To introduce students to different types of connections and the importance of detailing in structural engineering, Dr. Ross has created a slide template for a "Connection of the Day." Practicing engineers are invited to use the template to describe a structural connection to students. Figure: Dr. Brandon Ross and the North Carolina Department of Transportation.

The interviews were conducted via web conferences, which helped with logistics and allowed students to interview engineers from all over the country.

- **Equipment and supplies**. Clemson alumni and stakeholders are generous, and this generosity directly affects student learning. The hands-on experiments I have conducted with students were possible because the materials and supplies for the specimens were donated. Similarly, the Built Environment Laboratory at Clemson, where many student projects are performed, contains donated equipment and supplies.
- **Guest lectures**. Once or twice each semester, I have a practicing engineer visit my class and give a guest lecture. With some coordination, the lecture topic can be aligned with the course curriculum. Students like to hear from someone besides me, and I like having a rest! As an alternative to in-class lectures, practicing engineers also give presentations to the Clemson student chapter of the American Society of Civil Engineers. Guest speakers who provide free pizza tend to get the largest audiences.
- **Industry teaching assistants**. This past spring semester, a local engineer, who is a Clemson alumna, helped me as an industry teaching assistant. She joined each class period via web conference. It was nice having the perspective of a practicing engineer, especially when answering students' practical questions. I plan to scale up the concept this semester by inviting practicing engineers to mentor students as they work on class projects.
- **Internships**. The marketplace for new engineers is red hot! Most of my students are choosing between multiple job offers. When companies contact me about recruiting Clemson students, I encourage them to start by offering internships. Internships are a means for companies to engage students early and get a jump on their competitors. Internships also allow students and companies to take a "test drive" before offering or accepting full-time employment. These benefits of internships will remain even if the market for new engineers cools off.

I invite university faculty to contact members of the concrete bridge industry and get them involved with students. Likewise, I invite members of the concrete bridge industry to contact university faculty and find ways to engage with students. Every semester brings new students and new opportunities. I'm excited about the next 10 years of my career!

Approved Changes to the Ninth Edition *AASHTO LRFD Bridge Design Specifications*

by Dr. Oguzhan Bayrak, University of Texas at Austin

The 2022 annual meeting of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures took place June 20–23 in Pittsburgh, Pa. During that meeting, six working agenda items prepared by the AASHTO Technical Committee for Concrete Design (T-10) were approved. These agenda items were developed within the past several years and follow the 11 agenda items that were approved at the July 2021 virtual meeting (see the article in the Fall 2021 issue of *ASPIRE*®). Committee T-10 has one more year to prepare several additional agenda items, after which the revised version of the *AASHTO LRFD Bridge Design Specifications*[1] will be published as the 10th edition. This article provides an overview of the six recently approved agenda items.

1. **Lightweight Concrete Clarifications**
   The structural design provisions in Section 5 of the current AASHTO LRFD specifications are based on design concrete compressive strengths ranging from 2.4 to 10.0 ksi for normalweight and lightweight concrete, except where higher strengths not exceeding 15.0 ksi are allowed for normalweight concreteand are noted in the relevant articles. However, it has come to the attention of Committee T-10 that the language used to note the exceptions can be misconstrued and taken to mean that the section is only applicable to normalweight concrete. Additionally, some sections provide extra requirements for lightweight concrete that have been shown to be unnecessary. This agenda item clarifies the intent of the specifications and makes lightweight concrete and normalweight concrete designs more consistent.

2. **Concrete Anchors**
   In 2019, the American Concrete Institute modified the section on anchors in *Building Code Requirements for Structural Concrete* (ACI 318-19).[2] This agenda item makes changes to the *AASHTO LRFD Bridge Construction Specifications*[3] to make them consistent with the changes made in 2021 to Article 5.13 of the AASHTO LRFD specifications to address the modifications in the ACI 318-19 design provisions.

3. **Minimum Bar Bend Diameter**
   This change addresses an increase in the minimum bar bend radius for ties or stirrups published by the reinforcement fabrication industry for Grade 60 or lower reinforcement, and it provides clarity on minimum bend diameters for higher-strength bars when used as ties or stirrups. For reference, this modification was developed after a state department of transportation project received Grade 60 stirrup bars that were specified in contract documents to be bent to "CRSI [Concrete Reinforcing Steel Institute] criteria." The larger bend diameter (about 5 bar diameters) in conjunction with the precaster's standard strand template would have resulted in reduced concrete cover (see the Winter 2022 issue of *ASPIRE*®).

   ASTM A615[4] gives minimum pin diameters for bend testing of bent bars that are grade dependent for no. 3, 4, and 5 bars. For Grade 60 bars, the minimum pin diameter is 3.5 times the bar diameter d_b. For Grades 75, 80, and 100 bars, the minimum pin diameter is $5d_b$. The *CRSI Manual of Standard Practice*[5] provides stirrup and tie hook tables that include "finished bend diameters." The "finished bend diameter" is defined as the bend diameter measured after the bar is bent around a pin, which includes the "spring back" of bars after bending. CRSI chose to include only one value of "finished bend diameter" that will cover all grades of reinforcement. For Grade 60 stirrups, use of the larger diameter bend required for the higher reinforcement grades may result in inadequate cover or other modifications to standard details. A new article, C5.10.2.3, and indicates that the previously used smaller bends can still be obtained as a "special order."
   The clarifications offered by this agenda item are intended to eliminate confusion for detailing ties and stirrups and higher-strength reinforcing bars of all sizes.

4. **Reinforcing Bar Anchorage**
   Recent changes to the development length provisions of ACI 318-19[2] have resulted in a notable discrepancy between the AASHTO LRFD specifications and ACI 318-19. Moreover, the current AASHTO LRFD specifications do not have expressions for headed deformed bars, and the expressions for hooked bars frequently result in very different estimates from those given in ACI 318-19. The changes offered by this agenda item are intended to reduce the discrepancy between ACI 318-19 and AASHTO LRFD provisions while adopting a unified approach for tension anchorage design that is rooted in the concepts described in the *fib Model Code for Concrete Structures 2010*.[6] Overall, the new approach for reinforcing bar anchorage employs fewer equations. The empirical factors required to address a variety of common development length problems are also minimized. Finally, these revisions include provisions that apply to the anchorage of no. 14 and 18 straight reinforcing bars previously absent from the AASHTO LRFD specifications.

5. **Tensile Force in Concrete for Determining the Tensile Stress Limit**
   Article 5.9.2.3.1b of the current AASHTO LRFD specifications provides temporary tensile stress limits in prestressed concrete before losses. Tensile stress limits are provided for areas with bonded reinforcement sufficient to resist the tensile force in the concrete and for areas without bonded reinforcement. Larger tensile stresses are permitted in areas with sufficient bonded reinforcement. The tensile stress limit for areas without bonded reinforcement is generally construed to include areas where bonded reinforcement is not sufficient to resist the tensile force.

   The commentary to Article 5.9.2.3.1b prescribes a computational procedure for sizing the bonded reinforcement to permit the application of the larger tensile stress limit. However, the procedure is only accurate when the tensile stress zone is confined to a rectangular region, as illustrated in Fig. C5.9.2.3.1b-1. For nonrectangular regions, the description of the computation creates a conflict with the provided equation. The equation estimates the tensile force as the product of the top flange width and the average tensile stress, and the text of the commentary indicates the tensile force is the product of the average tensile stress and the tension area.

Contemporary wide-flange girders have thinner top flanges than older AASHTO Type I–IV girders. In wide-flange girders, the tensile zone often extends below the rectangular portion of the wide top flange and may extend into the web. The currently prescribed procedure significantly over- or underestimates the tensile force, depending on whether the computation is carried out using the commentary equation or the description provided in the specification. The prescribed calculation procedure also incorrectly estimates the tensile force in the concrete for other sections with top flanges and any type of section with internal voids when the neutral axis extends into the voided region.

The proposed revisions to C5.9.2.3.1b provide a general method for estimating the tension force in the concrete that is applicable to all girder section types regardless of the location of the neutral axis.

6. **Use of 0.7-in.-Diameter Strands in Precast Pretensioned Girders**
National Cooperative Highway Research Program (NCHRP) Project 12-109 proposed modifications to the AASHTO LRFD specifications to incorporate the use of 0.7-in.-diameter strands in precast, pretensioned concrete girders[7] and, based on NCHRP research, implement the use of 0.7-in.-diameter strands in practice. In this context, it is worth noting that AASHTO M 203/M 203M (ASTM A416/A416M)[8,9] includes 0.7-in.-diameter strands.

A 2.0-in. spacing between 0.7-in.-diameter strands has been shown to be adequate for the transfer of the force in the strands to the concrete without damage in the end regions of pretensioned girders. Therefore, the specification will permit the use of 0.7-in.-diameter strands on a 2-in. grid.

This agenda item covers the debonding rules that apply to 0.7-in.-diameter strands as well as the confinement reinforcement necessary in the end regions of pretensioned girders by employing an intuitive technique based on the strut-and-tie method.

These six agenda items are intended to improve the structural design and construction of concrete bridges by simplifying the design process, reducing ambiguity in design provisions, and establishing consistency where needed. Upcoming articles will look at each of these items in greater depth.

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National Bridge Inspection Standards—Part 1, A Brief History

by Samantha Lubkin and Dr. Joseph Hartmann, Federal Highway Administration

The Federal Highway Administration adopted the National Bridge Inspection Standards in 1971. Bridges, like this one on Foothills Parkway in Tennessee, are inspected following these standards. All Photos: Federal Highway Administration.

It is in the vital interest of the United States to have a strong national bridge inspection program and maintain an inventory of the nation's bridges. Regular and thorough bridge inspections are necessary to maintain safe operations and prevent structural and functional failures. Data on the condition and performance of bridges are necessary for bridge owners to make informed investment decisions as part of an asset management program.

Safety is the top priority of the Federal Highway Administration (FHWA). The agency's long-standing and successful national bridge inspection program has been at the core of highway bridge safety for 51 years.

The Silver Bridge collapse in Point Pleasant, W.Va., on December 15, 1967, brought nationwide attention to the issue of bridge safety and led to a systematic effort to ensure bridge safety at the national level. It was an event of historic significance and one that many would agree was a wake-up call that propelled the nation into a new era of bridge safety. FHWA adopted the National Bridge Inspection Standards (NBIS) in 1971, prompted by the U.S. Congress enacting the Federal-Aid Highway Act of 1968, which was a direct response to this tragedy.

By 1971, when the NBIS were established, the standards required that bridges be inspected at least once every two years, with special emphasis on identifying and assessing fractures, corrosion, and fatigue. FHWA was ultimately charged with using the data from bridge inspections nationwide to create the National Bridge Inventory and to standardize bridge inspector qualifications.

More than a half century later, FHWA's NBIS continue to ensure that only bridges safe for travel are open to traffic.

Working with FHWA division offices, state departments of transportation (DOTs), and federal agencies, hundreds of qualified inspectors evaluate the condition and safety of the nation's highway bridges. These bridges are inspected on a routine basis and the results are reported annually to FHWA. If inspectors deem a bridge unsafe, immediate action is taken, which may include closure, prompt repair, or load posting to limit the weight of vehicles that can use the bridge.

This national program has been successful in identifying bridge deficiencies, while federal and other funding programs have supported efforts to address these deficiencies. Because of the commitment to bridge safety by FHWA and state DOTs, the percentage of bridges in poor condition has dropped from 11.9% in 2000 to 6.9% in 2022.

While state DOTs are on the front lines conducting the inspections, FHWA provides the standards and oversees state programs to ensure safety and track bridge conditions nationwide. FHWA assesses compliance with the regulations through a detailed annual review process. Since FHWA established the NBIS regulations in 1971, the agency has continually worked to evolve, improve, and refine the bridge inspection program. Improvements have included requiring more rigorous inspections for certain steel bridges with less redundancy, requiring underwater inspections for bridges over water, and taking appropriate and timely follow-up actions when inspections identify critical safety issues. FHWA has also updated training requirements for bridge inspectors.

Another bridge tragedy occurred on August 1, 2007, when the Interstate 35W Bridge in Minneapolis, Minn., collapsed during the evening rush hour. This event led to renewed interest in the bridge inspection program.

In response, FHWA moved in 2011 from a qualitative process to a risk-based, data-driven process to assess compliance with the NBIS. FHWA now requires annual assessments of 23 specific inspection program areas to determine how well state DOTs and federal agencies are meeting the regulations. In addition, FHWA has dedicated more staff to support bridge inspection efforts. The aim is to improve consistency in bridge inspections and simplify efforts to identify challenges state by state. FHWA has also expanded the amount of data collected on bridges to monitor bridge conditions more closely nationwide.

FHWA continues to explore new ways of keeping bridges safe, including use of unmanned aerial vehicles (drones) and other cutting-edge tools to support or assist with bridge inspections. Among the technology-based tools used by bridge inspectors are nondestructive evaluation (NDE) techniques such as ultrasonic testing, which uses sound to detect subsurface characteristics, and infrared thermography, which uses the heat radiating from a bridge component as an indicator of its condition.

FHWA supports the application of science and advanced technology, including drones and NDE, to supplement bridge inspections. However, physical and visual inspection methods remain the primary tools that bridge inspectors use to assess the condition of a bridge.

While advanced technologies may not replace the human inspector at this time, they can accelerate inspections and improve inspector safety. NDE can be used to improve the accuracy of some inspections and the proper identification

Unmanned aerial systems (drones) are now being used to assist bridge inspectors. However, physical and visual inspection methods remain the primary tools that bridge inspectors use when assessing the condition of a bridge.

Nondestructive evaluation technologies can improve the accuracy of some bridge inspections. Here, an inspector checks post-tensioning tendon encapsulation with electrically isolated tendon technology. (For details on electrically isolated tendon systems, see the Concrete Bridge Technology article in the Spring 2019 issue of *ASPIRE*®.)

of certain issues. Bridge inspectors are trained to identify when these technologies are needed.

FHWA recently updated the NBIS to address statutory requirements, provide flexibility, and address ambiguities identified since the previous update to the regulation in 2009. Improvements include expanding the requirements to tribally owned highway bridges and to privately owned bridges that connect to a public highway on each end, updating the training and qualification requirements for bridge inspectors, and establishing a national certification for inspectors. In addition, requirements for the intervals between inspections were updated using a risk-based approach, and procedures for reporting and monitoring critical findings were established. The changes are primarily aimed at ensuring national uniformity for inspections and evaluations and clarifying responsibilities. For more information on these changes, stay tuned for part 2 of this article series, which will appear in the Winter 2023 issue of *ASPIRE*®. Information on the NBIS can be found at www.fhwa.dot.gov/bridge/inspection. Questions should be submitted to NBIS_SNBI_Questions@dot.gov.

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