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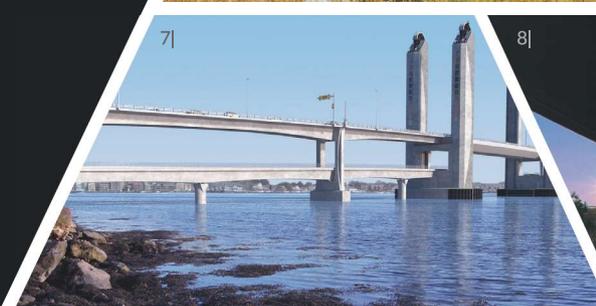


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Photo: H.W. Lochner Inc.



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Photo: Minnesota Department of Transportation.



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Photo: Nevada Department of Transportation.

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Responsibility, Authority, and Accountability

By W. Randy Cox, ASBI; Theodore Neff, PTI, and William N. Nickas, PCI

More than 15 years ago, the concrete bridge industry in the United States became aware of several isolated performance issues related to grouted post-tensioning (PT) tendons. In response, several responsible stakeholders—owner agencies, consultants, contractors, and technical institutes—mobilized to rectify and improve the state-of-the-practice. New PT durability details to enhance tendon protection and facilitate post-construction inspection were incorporated. Proprietary prepackaged grout materials were developed to replace field formulations and to improve overall grout performance. The technical institutes created education and certification programs related to PT grouting practices. Updated project specifications soon began to incorporate requirements for these certifications, the enhanced details, and the new grouts. The bridge engineering and construction community demonstrated it could work together to improve the long-term durability of post-tensioned bridges.

Later, experience showed that the use of the prepackaged grout materials had unintended consequences. While the engineered grouts were generally very effective in controlling grout bleeding, which had been the cause of most of the reported problems 15 to 20 years ago, some were found to be susceptible to a new problem—namely, segregation or soft grout. Research has shown that some of these proprietary mixtures included a high percentage of inert material that contributed to the formation of soft grout in some instances—particularly when excess water was used. When these new performance issues were reported in 2009, the industry again responded by revising the Post-Tensioning Institute grout material specification, M55, to prohibit the addition of inert fillers.

At the 2016 annual meeting of the AASHTO Subcommittee on Bridges and Structures, a state department of transportation (DOT) engineer reported that a bridge constructed in 2007 with prepackaged grout materials was now in distress. The DOT representative reported that the PT tendons contained grout with an excess amount of water—estimated to be twice the manufacturer’s recommended level.

These experiences have shown that both quality materials and proper workmanship are needed to

achieve reliability and long-term performance. The industry responded again with new specifications and new technologies. For more information, see the articles on pages 32, 34, and 36 in this issue.

When specified work procedures performed by qualified personnel go awry, corrective actions and perhaps revised jobsite procedures are needed. Conversely, the positive results achieved from consistently practicing quality work that leads to the good long-term performance of the vast majority of PT bridges should also be recognized.

During a recent safety workshop, presenter Michael Peelish used a slogan, “RAA” standing for **responsibility, authority, and accountability**. “RAA” can be defined for our industry as follows:

- **Responsibility**—the obligation to ensure that appropriate action is taken to follow the plans and specification procedures developed through standards of care from industry and set forth in the contract documents
- **Authority**—the jurisdiction and right to decide and take action to achieve a compliant installation by the installers and inspectors
- **Accountability**—to be answerable to the specified entity and the jurisdictional authority for a particular process or procedure

Prime construction contracts and subcontracting agreements must include the following items for assurance and to foster an accountable system:

- Clearly specify authority and responsibility of each party
- Provide adequately qualified (certified and permitted) personnel to meet the assigned responsibilities
- Conduct independent monitoring and assessment of individual processes
- Establish appropriate consequences for noncompliance or failing to take action
- Ensure consistent and unbiased application of accountable standards

We must do a better job of controlling quality, identifying problems during construction, and taking appropriate corrective action when necessary. We cannot rely solely on updated specifications to replace reliable workmanship and inspection. The entire bridge industry must make quality the responsibility of every single person involved in the project. 

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Cover

The Red Bridge Road bridge replacement outside Kansas City, Mo., designed by H.W. Lochner Inc. Photo: H.W. Lochner Inc.

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If you have a suggestion for a project or topic to be considered for *ASPIRE*, please send an email to info@aspirebridge.org

ASPIRE™ editorials are usually written by the editor-in-chief. However, recent issues in the bridge community compel us to use this space to address an industry issue.



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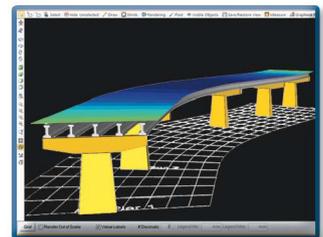
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CONCRETE CALENDAR 2017

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

January 8-12, 2017

Transportation Research Board 96th Annual Meeting

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

January 17-20, 2017

World of Concrete 2017

Las Vegas Convention Center
Las Vegas, Nev.

February 28-March 4, 2017

PCI Convention and National Bridge Conference at The Precast Show

Huntington Convention Center
Cleveland, Ohio

March 26-30, 2017

ACI Spring 2017 Concrete Convention and Exposition

Detroit Marriott at the
Renaissance Center
Detroit, Mich.

March 27-29, 2017

2017 DBIA Design-Build in Transportation Conference

Minneapolis Convention Center
Minneapolis, Minn.

April 10-11, 2017

ASBI Grouting Certification Training

J.J. Pickle Research Campus – The
University of Texas at Austin
Austin, Tex.

April 30-May 3, 2017

PTI Convention 2017

Hyatt Regency Atlanta
Atlanta, Ga.

May 9-10, 2017

FDOT, ASBI, and PTI sponsored Flexible Filler Certification Training

Tallahassee, Fla.

June 4-8, 2017

International Bridge Conference

Gaylord National Resort & Convention
Center
National Harbor, Md.

June 11-15, 2017

AASHTO Subcommittee on Bridges and Structures Annual Meeting

The Davenport Grand
Spokane, Wash.

June 12-14, 2017

fib Symposium 2017

Maastricht, The Netherlands

August 6-10, 2017

AASHTO Subcommittee on Materials Annual Meeting

Sheraton Grand Phoenix
Phoenix, Ariz.

September 6-8, 2017

2017 Western Bridge Engineers' Seminar

Portland Marriott Waterfront
Portland, Ore.

October 4-7, 2017

PCI Committee Days 2017

Loews Chicago O'Hare
Rosemont, Ill.

October 15-19, 2017

ACI Fall 2017 Concrete Convention and Exposition

Disneyland Hotel
Anaheim, Calif.

October 24-25, 2017

ASBI 29th Annual Convention

Marriott Marquis
New York, N.Y.

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CLOSE COMMUNICATION AID CREATIVITY

Lochner's two-part program keeps far-away offices in close touch so designers stay abreast of new techniques and trends to aid transportation-focused projects

by Craig A. Shutt

Designers throughout H.W. Lochner Inc.'s 31 offices stay in touch thanks to a concerted two-prong communication strategy. The format ensures they access new ideas and techniques that help them design a range of bridge projects nationwide and stay abreast of technological advancements such as building information modeling (BIM) and alternative-delivery formats, as well as innovations with materials such as concrete.

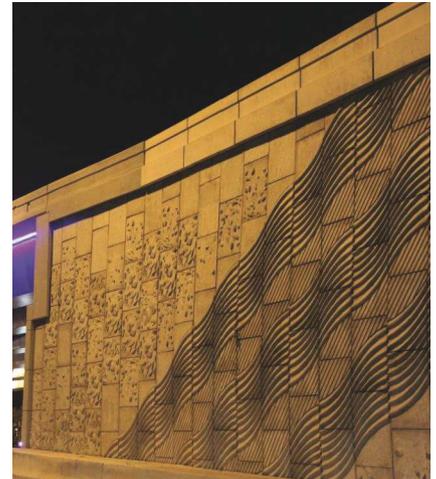
"Our goal is to generate strong relationships that help improve our efficiency and create innovative, cost-effective designs for our clients," says Brian Byrne, senior structural engineer and project manager in the East Hartford, Conn., office. The internal corporate-communication strategy incorporates a culture of work sharing, as well as systems that encourage knowledge sharing company wide.

Work-sharing formats include regular monthly conference calls within divisional groups to discuss new projects, progress on existing ones, and specific challenges, explains Chuck Craycraft, risk manager and vice

president in the Lexington, Ky., office. "We share ideas and experiences with structural issues of all types and take advice or input from others in the same group around the country." Adds Byrne, "It's great to hear what others have been doing, which may give me a spark that I can introduce to my project."

Knowledge sharing allows designers with a particular challenge to seek input at any point, says Byrne. It is coordinated by the Technical Resource Group (TRG) and operates through an intranet system called LochNET. "TRG connects firm leaders within specific disciplines to facilitate sharing of ideas about expertise and materials."

LochNET provides a forum for any employee to participate in knowledge exchange. For example, designers type in questions to which anyone can respond within specific technical communities. Employees also use this forum to post updates on projects and interesting challenges that arise. These then can be followed up with replies to the post, emails, and related documents. "The LochNET platform helps create strong relationships around the



A number of concrete innovations were incorporated into Lochner's work on the Interstate 95/Spanish River Boulevard Interchange project in Palm Beach County, Fla. All Photos: H.W. Lochner Inc.

country," Byrne says. "Of the 50 or so structural engineers we have on staff, I've probably worked with 80% or more to collaborate on designs."

Adapting to Challenges

The system allows the team to adapt to design and constructability issues as well



Lochner used nonproprietary equipment to slide into place the Lardo Bridge, carrying State Highway 55 over the North Fork of the Payette River in McCall, Idaho.



The 158-ft-long, single-span Lardo Bridge features 90-in.-deep precast, prestressed concrete girders and aesthetic details.



By bundling projects in the rapid-replacement program by the Pennsylvania Department of Transportation, Lochner helped reduce costs 558 replacement bridges by 25%. Many of the projects featured cast-in-place and precast concrete designs.



as issues with new owner requirements. That's especially helpful with multi-part bid options created in design-build and other alternative-delivery formats, where cost and schedule are separately weighted elements.

Lochner is no newcomer to the design-build format, Byrne notes. "We've been doing design-build since the late 1990s, and we encourage its use. When design-build can be applied well, it breeds innovation and new perspectives."

'When design-build can be applied well, it breeds innovation and new perspectives.'

It especially aids in minimizing risk factors, notes Craycraft. "Even with design-bid-build projects, we look to mitigate risk elements posed especially by time elements by working with the owner. But design-build gives us more opportunities to work with our contractor partners to identify alternatives and to assist the contractor in better estimating construction times."

Owners want faster schedules, but they don't want to increase risk factors to achieve them, he says. "In the design-build format, we can work with the general contractor to create alternative concepts that will meet the time needs and find efficient ways to improve construction times, which really helps with A+B-type contracts." These A+B-

type contracts combine factors for cost ('A' component) and scheduling ('B' component) to find the best combination.

Lochner has been involved in a number of public-private partnership (P3) projects, adds Byrne. "We expect to see more of these as owners are strapped for funds. P3s can work well to reduce costs and generate innovation."

Byrne points to Lochner's recent work for the Pennsylvania Department of Transportation's (PennDOT's) rapid-replacement program through a P3 agreement for the design, construction, financing, and maintenance of a large number of bridges. As a subconsultant on the technical team for an owner's side contract, Lochner evaluated approximately 1000 bridges as part of a larger program and assisted with the prioritization methodology. Ultimately, PennDOT designated 558 bridges for replacement.

Estimates indicated that the P3 format saved 25% as compared to a traditional delivery method. "By bundling a large number of similar bridges into one project, there were substantial efficiencies with design, construction, and maintenance."

ABC Techniques Expanding

Close communication also aids in developing new accelerated bridge construction (ABC) techniques. "We've been using ABC ideas for many years due to our many railroad clients," Byrne says. "They need to keep trains running and that means replacing bridges quickly. Now state agencies are taking

a closer look at what they've done and want to adapt those techniques to their own needs."

The capability to reduce user costs and minimize closures has made ABC methods attractive, but owners are wary of such significant changes to familiar construction techniques. "Most agencies have had good experience with ABC, but we have to demystify ABC techniques and make them more standard to convince agencies they will work," Byrne says. "We have to ensure we can minimize costs and make ABC methods the first choice."

ABC techniques were used successfully for the Lardo Bridge, carrying State Highway 55 over the North Fork of the Payette River in McCall, Idaho (see Winter 2016 issue of *ASPIRE*TM). The existing bridge was replaced in 2014 with Idaho's first federal-aid funded, design-build project. The 158-ft-long, single-span bridge features 90-in.-deep precast, prestressed concrete girders with aesthetic detailing, pedestrian viewing platforms, and a wider roadway to accommodate sidewalks and bike lanes.

The state designated a maximum 4-month closure (September to December) for this highly traveled tourist route. Innovative detailing of the abutments allowed them to be built as a rigid frame with the superstructure on temporary supports adjacent to the existing bridge, avoiding construction within the tight confines of the existing back spans. When the bridge closed, it was demolished and the new structure was slid into place.



Creating a Citizens' Advisory Board helped Lochner meet all of the stakeholders' needs when designing the Red Bridge Road bridge replacement in Kansas City, Mo.



Prestressed concrete girders were used for the 1100-ft-long Red Bridge Road bridge replacement that included a variety of amenities to commemorate the area's history.

'The use of a design-build format and the ABC techniques saved a significant amount.'

"The system used nonproprietary equipment that helps reduce costs further," Byrne notes. "It was a small project at \$3.6 million, but the use of a design-build format and the ABC techniques saved a significant amount."

The precast concrete girders were heavier and more challenging to transport to the site through the mountainous terrain, which added cost, he notes. But superstructure costs compared to steel alternatives were

so low that it more than made up the difference.

"The design-build environment allowed us to investigate sliding the bridge to take advantage of precast concrete's benefits. We were able to combine the best cost estimates with fast construction scheduling to win both the low cost 'A' component and the schedule 'B' component of the bid."

More Stakeholder Input

Minimizing user costs has become a critical element, as more communities take an active role in bridges constructed nearby. The way Lochner handles those efforts can be seen in its work on the Red Bridge Road improvements and bridge replacement in Kansas City, Mo. The bridge needed to be expanded to meet traffic needs,

but residents were concerned about potential right-of-way acquisitions and the proximity to three historic wagon trails.

Lochner created a Citizens' Advisory Board to work on balancing traffic and aesthetic needs. "We needed to gain the trust of all the groups involved and show our commitment to addressing their concerns. We wanted to ensure we had buy-in from everyone," says Byrne.

The new 1100-ft-long prestressed concrete girder bridge crosses the Blue River, railroad tracks, and a designated floodplain. The plan included a 10-ft-wide multi-use trail, sidewalk, 30 drainage structures, 3000 linear feet of storm sewer, and best management practices that treat all of the roadway runoff water before it enters the river.

Also included were overlook points with historical information boards, portraits of 10 prominent local residents, decorative railing, colored LED lighting, and aesthetically treated retaining walls to decrease grading operations. "It has become one of Kansas City's signature projects for sustainable design and public involvement."

Concrete Options

Lochner's designers also stay abreast of new materials and techniques, including those related to concrete. "We often implement concrete concepts as a solution to durability issues, depending on the budget," Byrne says. "For ABC designs, creating a precast concrete substructure offers a fantastic technique."

Concrete girders also come to the forefront in many design-build projects. "It's a real bonus when we need to expedite schedules," Byrne says. "Precast and cast-in-place concrete are always options given the key issues we typically deal with."

'Precast and cast-in-place concrete are always options given the key issues we typically deal with.'

Improvements in fabrication methods and improved material techniques have made concrete more versatile. "Concrete is denser and more durable than in past decades," he says. "We've looked at some of the new options, including self-consolidating concrete and lightweight concrete in our design-build projects, and we remain open to using them when the situation calls for it."

Several concrete innovations were included in Lochner's work on the Interstate 95/Spanish River Boulevard Interchange project in Palm Beach County, Fla. Lochner served as a roadway and structural engineering subconsultant on the design-build team and designed twin prestressed concrete Florida I-beam structures on the existing alignment. The 750-ft-long, five-span eastbound bridge featured two spans constructed of 10-ksi high-strength concrete, which eliminated the need

Lochner's Advances

H.W. Lochner Inc. was founded in Chicago, Ill., in 1944 by Harry W. Lochner Sr. and focuses its engineering design work in the surface civil-transportation industry, especially planning, environmental, design, construction management, and right-of-way acquisition. Over its seven decades of operation, it has expanded into rail, transit, and aviation infrastructure.

The employee-owned firm is home to more than 500 professionals, 15% of whom provide a suite of structural analysis, design, and inspection services. Lochner operates 31 offices in 16 states, with annual revenues of more than \$100 million.

In the 1990s, Lochner entered the alternative-delivery field as a lead designer on Salt Lake City's Interstate 15 reconstruction. The firm's portfolio includes more than 40 design-build projects, public-private partnerships, and construction manager/general contractor projects.

for two girder lines. "That created substantial construction cost savings," says Craycraft.

The firm modified standard 36-in.-deep Florida I-beams for a bridge widening over the El Rio canal as part of the project. The modified 24-in.-deep cross sections allowed the bridge to maintain its clearance without changing the profile.

Lochner also designed 940 linear feet of precast concrete sound barriers by creating customized designs that incorporated the area's 150-mph wind load requirements. The design leveraged the limited space for pilings by maximizing the panels' base width. "The design-build approach again helps us to optimize the custom designs," Craycraft says.

Technologies Aid Advances

Design advances are being aided by BIM, notes Andy Lohan, a structural engineer in the Chicago, Ill., office. "BIM is really taking over the industry. It offers huge potential for efficiencies when we can build parametric three-

dimensional models and adjust them as needed. Point-cloud survey data can provide millions of points of reference, which can provide a more comprehensive dataset than one would get from a traditional survey."

The ability for all design changes to be quickly evaluated and incorporated into drawings adds great efficiency. "It allows us to merge geometric and analytic models into a single source of truth for the project, which will increase our effectiveness and make us more competitive."

In all of their processes, Lochner looks beyond the status quo to what may be coming, he notes. "The United Kingdom is very advanced in the use of information modeling, so we're looking at what they're doing as a great starting base. We're also looking beyond our industry to what others are doing with technology that will help us in the future. One example would be gaming engines that link data to objects efficiently. There are some really promising ideas out there."

One idea with potential involves using drones for inspection work, he says. "It offers a lot more efficiency to get a comprehensive view of a bridge, especially areas difficult to reach. They can take high-resolution images and video in a much safer way, when we might not have had any access at all before."

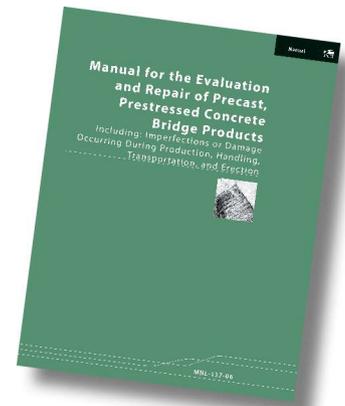
Lochner is getting into drone technology now and looking at the potential for how to maximize its usefulness. "We're evaluating how best to use it and on which structures it offers the most opportunity. The technology is moving very quickly, and we want to position ourselves to adapt to any changes as they develop."

As they learn more, team members will share their ideas and information on LochNET and through other collaborative platforms. "These sharing environments create a culture set up by leadership to help break down geographic barriers and encourage creativity," Byrne says. "It makes it feel like we're a small company while offering the wide experiences available from having the resources of a larger company." 

Defining the Service Life of Bridges

Relationship of service life to the repair of precast/pre-stressed concrete bridge components

by the late Dr. Dennis R. Mertz, University of Delaware, and Edward P. Wasserman, Modjeski and Masters



Confusion exists among bridge owners and designers regarding the terms *design life* and *service life* as evidenced by the fact that the two are often used interchangeably. Article 1.2 of the American Association of State Transportation Officials' *AASHTO LRFD Bridge Design Specifications*¹ defines design life and service life as follows:

- **Design Life:** "Period of time on which the statistical derivation of transient loads is based: 75 yr for these Specifications."
- **Service Life:** "The period of time that the bridge is expected to be in operation."

The definition of *design life* clearly delineates the intent of the authors of the specifications: Bridges designed in accordance with the AASHTO LRFD specifications should be able to resist the transient loads identified therein, projected over a 75-year period (the design life) with the uncertainty associated with its calibration.² The AASHTO LRFD specifications do yield bridges able to resist the transient loads of 1994 (the year of the publication of its first edition) projected over a 75-year period with the uncertainty associated with its calibration.² To be specific, the probability of a member "failing" because the applied loads exceed its capacity at the strength limit states in a 75-year period is 2 in 10,000, corresponding to a target reliability index β of 3.5.

However, the definition of *service life* is clearly not related to the design life or the probabilities associated with it. It is simply an expected period of operation. Thus the AASHTO LRFD specifications were not intended to result in bridges with a 75-year service life (or any other period) with any certainty. Indeed,

the probability of a bridge designed in accordance with the AASHTO LRFD specifications reaching a certain service life is unknown. This bears repeating: the AASHTO LRFD specifications do not currently define service life for bridges.

The AASHTO LRFD specifications do not currently define service life for bridges.

The use of the term design service life, a combination of the load and resistance factor design (LRFD) definitions, in *fédération internationale du béton (fib) Bulletin 34: Model Code for Service Life Design*³, among other relevant literature, is confusing and misguided. The authors would propose that the term target service life, much as the term target reliability index of the AASHTO LRFD specifications, is better terminology. The target reliability index represents the approximate reliability associated with the application of the AASHTO LRFD specifications strength limit states based upon the calibration of the specifications, as discussed previously.

By employing the partial probabilistic format of LRFD, the designer is not required to make probabilistic calculations. Service life and component deterioration are not well enough quantified to allow such calibration and are not of a nature to allow a quantification of the effects that can be readily represented in some probabilistic calculation. Thus, while the proportioning and detailing of components using the provisions of the AASHTO LRFD specifications represent good practice based upon experience, it cannot be associated with a specific service life in years. Such durability

provisions are termed "avoidance of deterioration" and "deemed-to-satisfy" approaches in *fib Bulletin 34*.

If and when service life performance data becomes available, efforts should be made to quantify and calibrate the effects. Efforts to quantify and calibrate service life are under way with projects such as the Federal Highway Administration's Long-Term Bridge Performance Program and the newly initiated NCHRP 12-108, which will culminate in a guide specification for service life design of highway bridges.

An example of bridge owners' confusion is represented in the project goals and objectives of a current design-build project in its Instructions to Proposers. One of the stated goals and objectives is "providing for a serviceable structure with a service life span of 100 years before major maintenance is required." While the future bridge owner is misguided in asking for a specific number of years of service (which cannot be guaranteed or even estimated with any degree of certainty despite the best efforts of some to claim this is possible), it rightly recognizes that the service life of a bridge is not necessarily defined by its replacement, but many times by merely a decision point for considering a major preservation action.

In a similar vein to the discussion of the previous example, some owner agencies have followed suit or have stipulated criteria such as target material property limits for concrete with the expectation of improving service life. Such requirements can be sound actions. However, if the specified material properties are not met, there is no scientific basis for determining a reduced service life. A

more rational approach contractually is to set incentive/disincentive clauses to adjust unit prices based on actual performance versus target performance. Owners should be further cautioned that the properties that can be achieved in a laboratory may not be what can be achieved in the field environment, and set reasonable targets.

Likewise, cases have been reported where contractors' requests to repair damaged precast concrete beams have been rejected on the premise that any damage, even if properly repaired, will automatically reduce the service life of the element. To hold such an opinion without the benefit of an engineering investigation is misguided. Successful repairs can be made in most instances by assessing the nature of the damage, its location, and the final stresses present in the repaired area after the successive stages of dead load and live load applications for both the service and strength limit states. The needed assessments can be determined and quantified by qualified engineers through calculation and competent engineering judgment. This is important, as deviation from

specifications and plans can occur at any stage of constructing a project, with precast/prestressed concrete products being only one example.

To this end, Precast/Prestressed Concrete Institute (PCI) has published a *Manual for the Evaluation and Repair of Precast, Prestressed Concrete Bridge Products*⁴ for the use of owners, engineers, and fabricators to help guide a rational approach to the decision-making process. The introductory chapter of this manual provides a step-by-step outline for conducting investigations that lead to well-reasoned engineering decisions, followed by discussion as to causes and remediation. Successive chapters provide proven acceptable repair details and guidance on implementation of repairs that can reasonably assure those repairs will meet the target service life intended. The ultimate value of this manual depends on the sound investigation and engineering judgment of an owner-engineer-fabricator team working together in good faith to solve the problem at hand.

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EDITOR'S NOTE

For more information regarding test procedures for long-service-life patch materials, see the Yang et al. paper from the March-April 2016 issue of PCI Journal. This research was funded by the Tennessee Department of Transportation.



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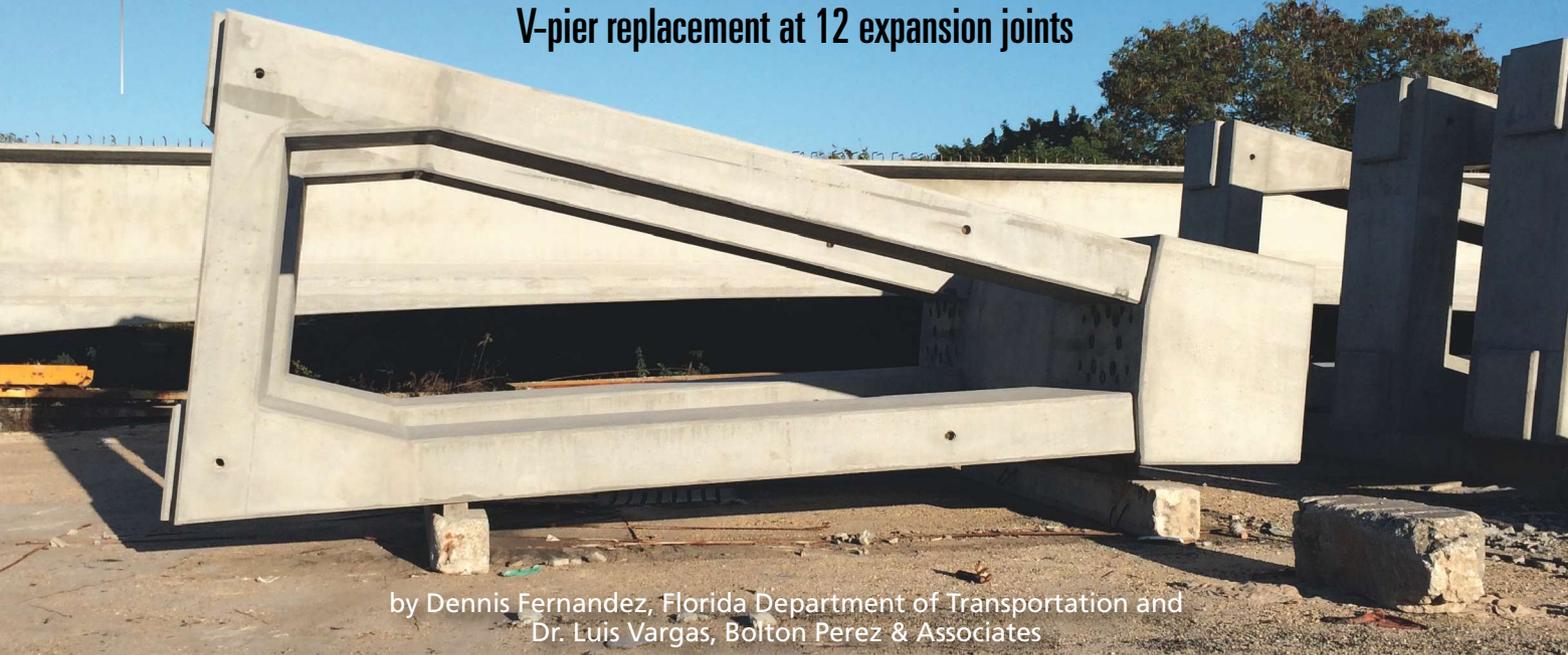
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Long Key Bridge Pier Replacement

V-pier replacement at 12 expansion joints



by Dennis Fernandez, Florida Department of Transportation and Dr. Luis Vargas, Bolton Perez & Associates

Precast concrete replacement pier in storage at precaster's facility in Tampa, Fla. Photo: Kurt Podoll, Standard Concrete.

The first real bridge construction across the Florida Keys began in April 1905 when a 100-ft-long drawbridge was put in place. The first important long bridge was the Old Long Key Bridge, which consisted of 2.7 miles of concrete arches. This was one of the first major trestle-type structures completed and it withstood, without damage, the most disastrous storm on record in this part of the state, the Hurricane of 1909.

The Old Long Key Bridge was removed from the state highway system in 1982 after the existing Long Key Bridge was opened. The existing Long Key Bridge is located in the Florida Keys (MM 63.2)

and was completed in 1981. It was the first post-tensioned concrete segmental bridge built in the state of Florida. At 12,152 ft long, it serves as the only route into the Florida Keys.

Existing Bridge Description

The bridge was the first precast concrete, segmental box-girder bridge in the world to be erected using the span-by-span method of construction with external tendons. The bridge is prestressed longitudinally using post-tensioned external tendons and the deck is transversely prestressed using pretensioned strands. The bridge was constructed using the dry joint construction method. All non-

prestressed steel reinforcement is epoxy-coated.

There are 13 continuous units, with each unit consisting of seven or eight spans. A typical unit is 944 ft long between expansion joints. Movement was accommodated at the base of the existing V-piers. Thermal, creep, and shrinkage movements take place about the neutral point at the middle pier of each eight-span unit. The bridge foundations are drilled shafts, designed to carry longitudinal forces exerted by the stiffness of the bearings, V-piers, and superstructure interaction. The bridge works as a fully integrated system.

profile

LONG KEY BRIDGE PIER REPLACEMENT / MONROE COUNTY, FLORIDA

PIER REPLACEMENT DESIGN ENGINEER: HDR, Miami, Fla.

PIER REPLACEMENT DESIGN PEER REVIEW: Corven Engineering Inc., Tallahassee, Fla.

PRIME CONTRACTOR: Johnson Brothers Construction, Lithia, Fla.

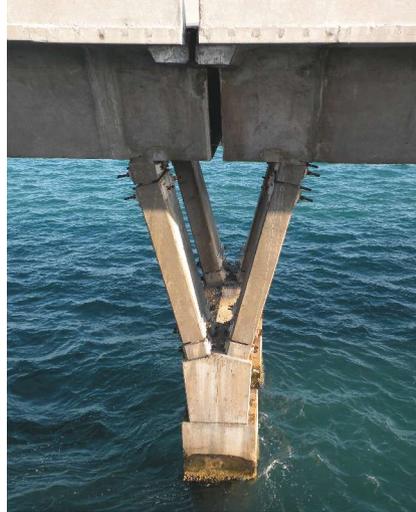
PRECASTER: Standard Concrete, Tampa, Fla.—a PCI-certified producer

CONTRACTOR'S SPECIALTY ENGINEER (DESIGN AND DETAILING OF FALSEWORK, MEANS AND METHODS): A2B Engineering LLC, Tampa, Fla.

CONTRACTOR'S SPECIALTY ENGINEER (FIELD SERVICES): BMA Consulting Engineers, Hollywood, Fla.

CONSTRUCTION INSPECTION: WSP|Parsons Brinckerhoff, Tampa, Fla.

Each pier foundation consists of two 42-in.-diameter concrete drilled shafts with cast-in-place caps that were connected by a precast concrete tie. Longitudinal movements of the bridge due to long-term deformation, thermal, and horizontal loads were accommodated by shear deformation of bearing pads at the bases of the interior V-piers. At the expansion joint locations, the V-pier legs are hinged at the top and bottom.



Side view of original Vpiers with Freyssinet hinges at top and bottom. Photo: Luis Vargas.

Existing Bridge Condition

The bridge had a National Bridge Inventory (NBI) rating of 4 (poor condition) due to the condition of the 12 piers at the expansion joints. By contrast, the NBI superstructure rating for this bridge was 6 (satisfactory condition). The Florida Department of Transportation (FDOT) policy is to repair or replace bridges with an NBI rating of 4 or less. Bridges of this age were designed to achieve a service life of 50 years. In order for this bridge to reach its service life of 50 years, repairs were needed.

The 12 piers at the expansion joints were designed to accommodate the longitudinal expansion and contraction of the concrete segmental superstructure due to thermal fluctuations by allowing rotation about the Freyssinet concrete hinges. Somewhere during the design process, steel rods were added to pass through the center of the hinges. These rods effectively limited the rotation of the hinges, causing the piers to crack.

These piers are located in an extremely aggressive (saltwater) environment. Water entered the cracks in the pier concrete causing deterioration and corrosion of the reinforcing steel in the vicinity of the hinges. The piers were subsequently reinforced by temporary

plates and external post-tensioning bars in order for the bridge to continue functioning. FDOT has been aware of the condition of the piers since 1990, and several unsuccessful attempts have been made over the years to fund the replacement of the 12 piers at the expansion joints.

If the bridge continued to deteriorate without repairs, the bridge's load-carrying capacity would have decreased, which would have



Photo of the existing V-pier with the 1908 arch structure in the background. The galvanized compression plates installed shortly after construction are visible. Photo: Luis Vargas.



Precast concrete replacement pier ready for transportation from precaster's plant in Tampa, Fla. Photo: Kurt Podoll, Standard Concrete.

eliminated many of the overweight permit loads that businesses in the area currently depend on and load posting may have been required. This would have had a negative effect on commerce and prosperity of the region. If the bridge was not repaired the damage also could have spread to other parts of the structure, and may have ultimately reached a point where temporary closure was needed to facilitate more extensive repairs. The cost for replacing the Long Key Bridge was approximately \$150 million and the cost to replace the 12 V-piers at the expansion joints was about \$14.4 million.

Replacement of V-Piers

The replacement project encompasses the 12 V-piers at the expansion joints and has the following requirements:

- Keep the same original appearance.
- Maintain uninterrupted traffic on the bridge at all times since it is the only evacuation route of the Lower Keys during hurricane season.
- Meet stringent environmental requirements of the Florida Keys National Marine Sanctuary.
- Do not allow construction activities to interfere with the nearby historic Old Flagler Bridge.

FLORIDA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Hilman Rollers, Marlboro, N.J.; and VSL, Hanover, Md.

BRIDGE DESCRIPTION: This 12,152-ft-long single-cell segmental concrete box-girder bridge was the first segmental bridge built in Florida and is one of the series of bridges in the viaduct serving the Florida Keys. It was built in 1982 using span-by-span construction to erect 722 segments. The structure carries two lanes of traffic and a major utility—the drinking water supply line. It is the only concrete segmentally constructed structure to use transverse prestressing and a pretensioned deck.

REHABILITATION STRUCTURAL COMPONENTS: Precast concrete V-piers with grouted connections, cementitious grout, and high-strength post-tensioning bars

BRIDGE CONSTRUCTION COST: \$14.4 million for the pier replacement



Special lifting and handling procedures were established. Photo: Kurt Podoll, Standard Concrete.

- Select a structural system that accelerates construction resulting in minimum inconvenience to the public.

Several design considerations were incorporated into the engineering of the replacement project. Since the bridge already had 30 years of service, most long-term deformation due to creep, shrinkage, and steel relaxation has occurred. Therefore, the proposed system only needed to accommodate thermal movements and lateral loads. This was accomplished by using a precast concrete inverted delta-frame that closely resembles the appearance of the existing bridge piers.

The precaster carefully designed the forming system to facilitate removal



Temporary devices used to lock expansion joints during pier replacement. Photo: FDOT.

of the interior core forms and to use self-consolidating concrete. Lifting and handling procedures were established by the project team to meet the FDOT requirements to minimize cracking. These prefabricated elements were manufactured in Tampa, Fla., and shipped to the project site.

Elastomeric bearing pads located on top of the delta-frame support the segmental concrete box girder and accommodate lateral forces and longitudinal displacements. The new precast concrete V-pier has a pier cap, which is designed with a special moment connection (similar to other accelerated bridge construction [ABC] connections in high seismic areas) to the existing drilled shafts, providing continuity to the foundation similar to the original design.

The replacement required slight modifications to the appearance of the V-piers without affecting the remaining members of a bridge unit. Since connection of the V-pier legs to the superstructure was no longer monolithic, the bridge is transversely restrained by a shear key that was introduced between the delta-frames. Also, the inclination of the V-pier leg in the original monolithic detail introduced a compression force in the bottom flange of the box girder that reduced the service-load moment by 8%. Since the new V-pier detail does not produce precompression in the box girder, the service load moment was no longer reduced. Analysis indicated that these structural changes were not detrimental to the performance and load carrying capacity of the bridge.



Temporary support system supporting spans as existing V-pier is being removed. Photo: FDOT.

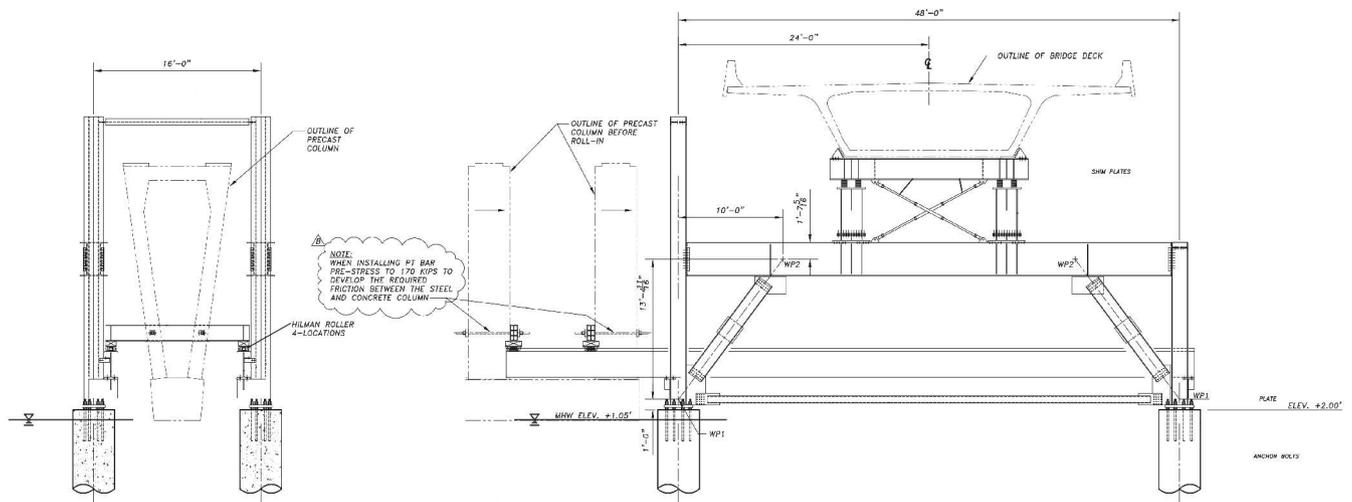


Reinforcing bar cage, grouting tubes, and steel duct for connection between drilled shaft and replacement pier. Photo: Kurt Podoll, Standard Concrete.

The temporary support system (TSS), envisioned and engineered to support the box girder during the replacement of the V-piers, consisted of an innovative steel structure that was unique, safe, and efficient. It was designed with the characteristics of a permanent structure as it carried the bridge and traffic while the substructure was being replaced. The TSS was supported on temporary drilled shafts and included a sophisticated jacking and monitoring system to transfer all dead and live loads from the superstructure without perceptible displacements. As the replacement work was done within the ecologically sensitive Florida Keys National Marine Sanctuary, the TSS avoided special permitting requirements by being independent of the existing bridge (not



Temporary support system spanning between temporary outboard drilled shafts supporting the bridge after the V-pier has been removed. Photo: FDOT.



Shop drawing excerpt from temporary support system frame showing replacement scenario. Figure: A2B Engineering LLC.

using the existing bridge for support). The TSS addressed several aspects of constructability: it was reusable, accommodated existing foundation and superstructure conditions, and allowed for all assembly and disassembly operations to be done above water.

The construction activities started in March 2013 and ended in December 2015. The average V-pier replacement took approximately 1 month. The construction sequence was as follows

1. Install temporary drilled shafts.
2. Install the temporary support system.
3. Install stabilizing system to the existing V-pier.
4. Restrain expansion joint pier

segment of adjacent units with post-tensioning devices.

5. Preload jacking devices with 80% of jacking loads.
6. Monitor deflections and possible settlement for about 6 hours.
7. Jack the structure to transfer superstructure reactions to the temporary support system.
8. Saw cut or burn (or both) connections at the hinges (top and bottom).
9. Disconnect and remove the existing V-pier cap and footings by wire cutting at the top of existing drilled shafts.
10. Slide in and level the new V-pier.
11. Drill holes in the existing drilled shafts; install and grout steel bars.
12. Install bearing pads and retract jacks to transfer load to new pier.

Conclusion

Replacing the 12 piers at the expansion joints was by far the most prudent use

of state funds. The replacement of the piers eliminated the existing structural deficiency, making it possible for the bridge to achieve its service life of 50 plus years. **A**

Dennis Fernandez is the structures maintenance administrator at the Florida Department of Transportation, District Six in Miami, Fla. Dr. Luis Vargas is chief bridge engineer at Bolton Perez & Associates in Miami, Fla., and former engineer of record with HDR when the rehabilitation was completed.

EDITOR'S NOTE

See the article in the November-December 1980 PCI Journal by Thomas Gallaway for more information on the original design and construction of this bridge. Portions of this article are based on a paper by Vargas for the 2015 National ABC Conference.



New pier seated in temporary support system and ready for side launch into permanent position. Photo: FDOT.



With the new V-pier in position, anchor holes were used as drilling template for establishing connections into drilled shaft. Photo: FDOT.



High-strength bar installation and cementitious grouting operations using ABC connection details. Photo: FDOT.

Bridge 85851

Minnesota opens new bridge ahead of schedule and using construction manager/general contractor procurement methodology for the first time

by Terry Ward and Keith Molnau, Minnesota Department of Transportation

On August 27, 2016, Minnesota Department of Transportation and its project partners opened Bridge 85851 with a community celebration attended by over 700 people. Photo: Minnesota Department of Transportation.

On August 27, 2016, the Minnesota Department of Transportation (MnDOT) and its project partners opened the new Bridge 85851 with a community celebration that was attended by over 700 people. The bridge was built in only 2 years and opened ahead of schedule, with a cost below the original budget. This project performance required the use of a new procurement methodology, a strong team of engineers and project managers, a high-quality contractor, and a bit of luck.

Project History

Existing Bridge 5900, which spans the Mississippi River in Winona, Minn., was opened to traffic in 1942 and has provided an important regional crossing

of the river. It has 24 spans, consisting of a through-truss, deck-trusses, steel beams, and concrete T-girders, and was redecked in 1985. It is fracture-critical and scour-critical and was closed for 2 weeks in 2008 for gusset plate repairs. Recent inspections had shown an acceleration in the rate of deterioration and the bridge was in need of repair.

Federal laws provide for the protection of historic bridges, and existing Bridge 5900 was eligible to be listed on the National Registry of Historic Places (NRHP). After several years of study of various alternatives that would comply with a no adverse effect finding and continued NRHP eligibility, planning efforts settled on an alternative that included rehabilitation of the cantilever

through-truss (the main three spans), along with replacement of the approach spans. This alternate also included construction of a new girder type bridge on a parallel alignment. The total project cost estimate was \$189 million.

Project Goals

Based on extensive outreach with our project partners, the overriding goals for the Bridge 85851 project became

- build the new bridge as quickly as possible,
- keep the river crossing open during construction, and
- preserve the historical importance of existing Bridge 5900 with both a no adverse effect and continued NRHP eligibility.

profile

BRIDGE 85851 / WINONA, MINNESOTA

BRIDGE DESIGN ENGINEER: FIGG Bridge Engineers, Denver, Colo., and Tallahassee, Fla.

DESIGN PEER REVIEW: Parsons Transportation Group, Minneapolis, Minn.

CONSTRUCTION MANAGER / GENERAL CONTRACTOR: AMES Construction, Burnsville, Minn.

INDEPENDENT COST ESTIMATE: Armeni Consulting Services, Suwanee, Ga.

PRECASTER: Cretex Concrete Products, Elk River, Minn.—a PCI-certified producer

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

CONSTRUCTION INSPECTION: MnDOT District 6 Construction Unit, Rochester, Minn.; HDR Engineers, Minneapolis, Minn.; Stantec Engineers, St. Paul, Minn.; Mead & Hunt, LaCrosse, Wis.; and FIGG Bridge Inspection, Tallahassee, Fla. (Segmental)

Project Challenges

In April 2013, the project was struggling with meeting the project goals within the traditional design-bid-build (DBB) methodology. The letting date was slated for March 2015 and was significantly behind schedule, based primarily on the delivery of 29 parcels of new right of way (ROW). These delays—along with the environmental assessment not being finalized and final design consultant contracts and environmental permits not having been initiated—were viewed as almost insurmountable obstacles with traditional DBB procurement.

The project team foresaw two major challenges. First, building the new bridge fast required breaking the project into multiple work packages and removing ROW from the critical path. Then, to ensure the rehabilitation and reconstruction of Bridge 5900 were able to move forward, MnDOT needed insight into the costs of the through-truss rehabilitation and a thorough understanding of the risks involved. Similar bridge rehabilitation projects had a history of coming in well over the estimated amounts. With the scale of this rehabilitation work, a different approach was clearly in order.

Final Design and CM/GC Procurement

With preliminary design studies nearing completion in May 2013, the MnDOT District team and Bridge Office team agreed to a very aggressive schedule using the construction manager/general contractor (CM/GC) project delivery method for the final design and construction of Bridge 85851 just upstream of the Bridge 5900.



The segmental box girder, which mirrored the historic cantilever through-truss, gained acceptance and was also the most cost-effective alternative. Photo: FIGG.

The proposed schedule was to begin construction of the river piers in July 2014 and put traffic on the new bridge by the end of 2016, both viewed as almost impossible challenges. This would then allow two-way traffic on the new bridge, after which the needed rehabilitation of the historic truss could begin.

The CM/GC procurement method allowed the project team to break the project into smaller work packages. With no ROW needed for construction of the main river spans and north approach, Bridge 85851 could be designed and constructed on an accelerated schedule focusing on materials procurement, river access, and foundations. Subsequent work packages included the remainder of the new bridge and grading plans, followed by the rehabilitation of the historic bridge.

With schedule goals formalized, MnDOT procured final design consultant contracts and selected separate firms for engineer of record and peer reviewer for new Bridge 85851. MnDOT also procured its first CM/GC, along with a separate independent cost estimate for pricing verification of the contractor's estimate at various phases of the project.

Structure Type Selection

The concrete box-girder structure type was selected for the new bridge based on criteria that included assessment of the visual impact to the historic bridge. Since 1941, the graceful historic cantilever through-truss had become an iconic structure in Winona. Preliminary



The main river spans utilized the cast-in-place balanced cantilever construction method. Photo: Minnesota Department of Transportation.

MINNESOTA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Form Travelers: VSL, Fort Worth, Tex.; Formwork: EFCO, Des Moines, Iowa; Reinforcement Fabricator: CMC Rebar, Kankakee, Ill.; Bearings and Expansion Joints: DS Brown, North Baltimore, Ohio; and Ornamental Metal Railing: Utility Sales and Supply Inc., Loretto, Minn.

BRIDGE DESCRIPTION: A 2295-ft-long structure composed of a four-span, cast-in-place, post-tensioned concrete slab and five spans of 63-in.-deep precast, pretensioned concrete girders on the south approach, transitioning to a three-span, single-cell, segmental box-girder unit built using the balanced cantilever method with form travelers, followed by four spans of 63-in.-deep precast, pretensioned concrete beams on the north approach

STRUCTURAL COMPONENTS: Segmental spans are 242, 450, and 242 ft. A thin, variable depth (1 ft 9 in. minimum, 3 ft 3 in. maximum) post-tensioned slab with spans of 15, 50, 57, and 60 ft was used to obtain vertical clearance over local streets for the south approach in Winona, Minn. The remainder of the approaches were 130-ft-long, 63-in.-deep precast, pretensioned concrete spans aligned with the spans of the adjacent historic bridge

BRIDGE CONSTRUCTION COST: \$77 million for Bridge 85851 and associated roadway work

AWARDS: *Roads and Bridges* Top 10 Bridge Awards, 2015 (#7)

engineering studies set maximum approach grades of 5% (for ADA compliance of the 12 ft wide shared use pedestrian path) with a variable structure depth of 21 ft maximum at the haunches and a 242-450-242 ft span arrangement to align the piers with the adjacent historic bridge. The bottom slab of the box girder tapered from 4 ft thick at the face of the pier diaphragms to a minimum of 9 in. thick at about 140 ft from the centerline of the pier.

Thinner structure type alternatives were also reviewed, including tied arch and cable-stayed superstructure types, but overhead arches or towers would visually compete with the cantilever through-truss. Thus, the haunches of the segmental concrete box girder, which mirrored the historic cantilever through-truss, gained acceptance and was also the most cost-effective alternative.

The balanced cantilever method of construction was initially selected by MnDOT over cast-in-place (CIP) concrete back-spans on falsework due to concerns with tall falsework within the levee and river. The CM/GC concurred that the proposed structure type was the best fit for this location and the method was finalized.

Project Management

Upon selection of the structure type for the new bridge, much work was needed prior to initiating final design. Multiple critical path schedules were juggled by MnDOT project managers, working with consultants to keep the project on the aggressive schedule that had been set. The MnDOT Bridge Office took the lead on concurrently obtaining the Coast Guard Permit and procuring final design consultant contracts. The MnDOT District 6 Office worked on a parallel path with consultants to obtain other permits, ROW acquisition, and municipal consent from the city of Winona, and to develop the environmental assessment.

A volunteer-based visual quality review committee was formed with local Winona representatives to develop the aesthetics and architectural details for the new bridge. The process required separate review by historians to ensure compliance with a no adverse effect

finding. The preliminary design was completed leading up to a January 2014 final design kick-off meeting with the final design consultants and CM/GC.

Foundation Design and Durability Considerations

For the foundations, 42-in.-diameter open ended piles had been successfully used on past projects in Minnesota, and appeared to be the viable alternative for resisting vessel collision loads. The CM/GC had the appropriate pile-driving hammer available from construction of the nearby Dresbach Bridge (see Summer 2016 issue of *ASPIRE™*), and provided input that the same foundation type was preferred and more economical than drilled shafts or other alternatives.

Bridge 5900 was originally constructed on timber piles and foundation retrofitting was necessary to strengthen the historic bridge for current design load requirements for vessel collision forces. To strengthen the lateral capacity of the old piers adjacent to the navigation channel, a CIP strut was evaluated that would brace the 75-year-old piers off the newly constructed piers of Bridge 85851. The CM/GC recommended the use of a precast concrete strut instead of the CIP strut, which would have required de-watering. Ultimately, a receiver bracket was cast into the footings of the new Bridge 85851 to support a concrete-filled 42-in.-diameter pipe from leftover pile cut-offs that would bear against the side of the old footing.

To address long-term durability, MnDOT included several provisions for a 100-year design life. The segmental box girder was designed with 50 psi residual compression in the top of the deck and with stainless steel reinforcing bars in the closure segments and in the top slab of typical segments. High-performance concrete with contractor-provided mixture proportions was specified with a compressive strength of 7 ksi; ranges on cement, fly ash, and slag; a requirement for low absorption aggregates; and limitations on shrinkage and scaling.

New Bridge Construction

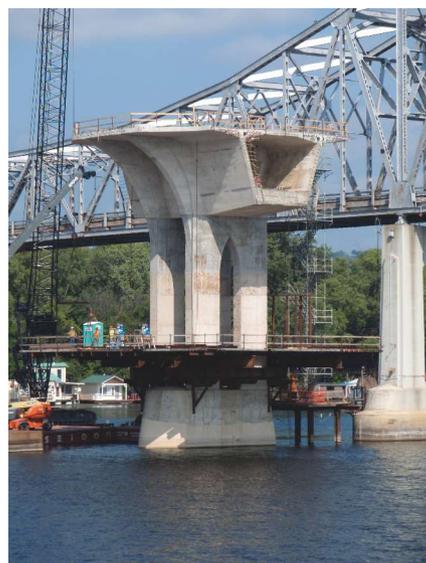
Construction on the new bridge began in July 2014, and the construction team worked through the winter of



An early foundations contract was used to accelerate construction of the river pier foundations. Photo: Minnesota Department of Transportation.

2014-2015 to get the new river piers up and out of harms' way of potential Mississippi River flooding. To meet the aggressive schedule, no flooding delays could be allowed. A unique idle marine fleet provision was implemented and cofferdam elevations were set lower than typical. This reduced the construction cost of the cofferdams and better shared the risk between the contractor and owner. Thus, the goal of getting up and out of the way of flooding was accomplished and MnDOT saved approximately \$490,000.

Work continued in 2015 with the start of the CIP main river spans. Fifty segments were cast, many during the



The pier table was constructed one-half segment out of balance with 28 ft projecting into the main span and 20 ft into the back span. Photo: FIGG.

harsh Minnesota winter months, with the resulting structure being ahead of schedule in the spring of 2016.

CM/GC Advantages

The four work packages for the new bridge and associated roadway work cost \$77 million, which is around \$2.5 million below the letting amounts. In addition, the project team documented over \$10 million in cost savings directly attributed to the use of the CM/GC procurement methodology and the partnership efforts of the entire team.

MnDOT used a CM/GC collaborative process with a first-time construction engineering innovation that included the engineer of record (EOR), peer reviewer, CM/GC, and the post-tensioning subcontractor. Models developed by the EOR for the design and peer review were updated with information provided by the contractor's suppliers, leading to a seamless effort to produce integrated segmental girder shop drawings by the EOR. Collaboration before letting allowed for early production of complex pier table segments, and other segments that were on the critical path, rather than the contractor beginning development of shop drawings after



Form travelers with suspended heated enclosures enabled concrete for the segments to be placed throughout the winter. Photo: FIGG.

letting. This process also allowed for early collaboration with the form traveler supplier to review form traveler details and make adjustments. This took an entire year off the construction schedule. ▲

Keith Molnau is the bridge design project manager with the Minnesota Department of Transportation in Oakdale, Minn., and Terry Ward is the Winona project manager with the Minnesota Department of Transportation in Rochester, Minn.



Main river piers are 3 ft by 9 ft 6 in. and extend 45 ft above the top of the ice breaker to the pier table. Photo: FIGG.

AESTHETICS COMMENTARY

by Frederick Gottemoeller



Building a new bridge parallel to an existing bridge is always a difficult aesthetic problem, especially where, as in this case, the old bridge is recognized for its historic nature and aesthetic quality. One can always just duplicate the old bridge, unless its materials and technology are so outdated as to make that strategy hopelessly expensive. That was the case in Winona. So, that establishes the aesthetic challenge: to create some visual relationship with the old bridge while using completely different materials and construction methods, and to do it in such a way as to not create an adverse effect on the old bridge or compromise its continued eligibility for the National Register of Historic Places.

The designers decided to base the visual relationship on the graceful downward curve of the top chord of the cantilever truss. They answered that with an equally graceful upward curve of the soffit of the haunched girder. The result is almost a mirror image, a yin-yang relationship that turns the two bridges into an ensemble, in spite of the fact that they are completely different materials, technologies, and colors. The most powerful visual aspect of any bridge is its overall shape, and here the designers have made that shape work for them very well.

Frederick Gottemoeller is an engineer and architect, who specializes in the aesthetic aspects of bridges and highways.

PROJECT

Rhomberg Avenue Bridge

Upper Bee Branch Creek Restoration Project bridges community, creativity, and collaboration

by Michael A. Jansen, IIW P.C.

When the city of Dubuque, Iowa, launched its flood mitigation project—the largest capital improvement project in the city’s history—residents and the city focused on how a watershed solution could also serve as a catalyst for neighborhood reinvestment and revitalization. Through many public meetings, it became clear residents were not only concerned about eliminating devastating flooding, but they wanted amenities that would support a sustainable neighborhood with enhanced quality of life. This flood mitigation project will protect over 1300 homes and businesses. The project has the added value of improving water quality and property values, stimulating investment, and enhancing quality of life.

The Bee Branch Creek Restoration project takes former industrial, commercial, and residential properties and creates an open waterway with a linear park—complemented by a highly visible bridge, culvert, and overlook structures, recreation green space and trail, outdoor amphitheater, community orchard, and playground equipment.

The Lower Bee Branch Creek segment includes a channel connected to a large expanse of open water that

wraps around a former industrial site. Construction of the Lower Bee Branch Creek started in the fall of 2010 and was completed in November of 2011. The Upper Bee Branch Creek segment, currently under construction, will have a 2300-ft-long landscaped creek and green space that accommodates low intensity recreational use.

Community Expectations

In August 2003, the Dubuque City Council formed a committee to study the flooding issues in the North End and Washington Street neighborhoods. To help the committee evaluate solutions, they established six criteria,

including preservation of local businesses and services, minimization of property acquisitions, affordability, preservation of neighborhood access and connectivity, minimize health and safety risks, and minimize impacts to quality of life and the environment. The city council moved forward with the recommendation to create an open channel by day-lighting the Bee Branch Creek.

In the fall of 2008, the design for the Bee Branch Creek Restoration was initiated. In order to understand the community’s vision for the project, the design team held a series of



Completed Rhomberg Avenue Bridge. All Photos and Figures: IIW P.C.

profile

RHOMBERG AVENUE BRIDGE / DUBUQUE, IOWA

BRIDGE DESIGN ENGINEER: IIW P.C., Dubuque, Iowa

PRIME CONTRACTOR: Tricon Construction, Dubuque, Iowa

BRIDGE SUBCONTRACTOR: Jim Schroeder Construction, Bellevue, Iowa

STAMPING SUBCONTRACTOR: D&D Superior Concrete Construction, Dubuque, Iowa

PRECASTER: Crest Precast Inc., LaCrescent, Minn.—a PCI-certified producer

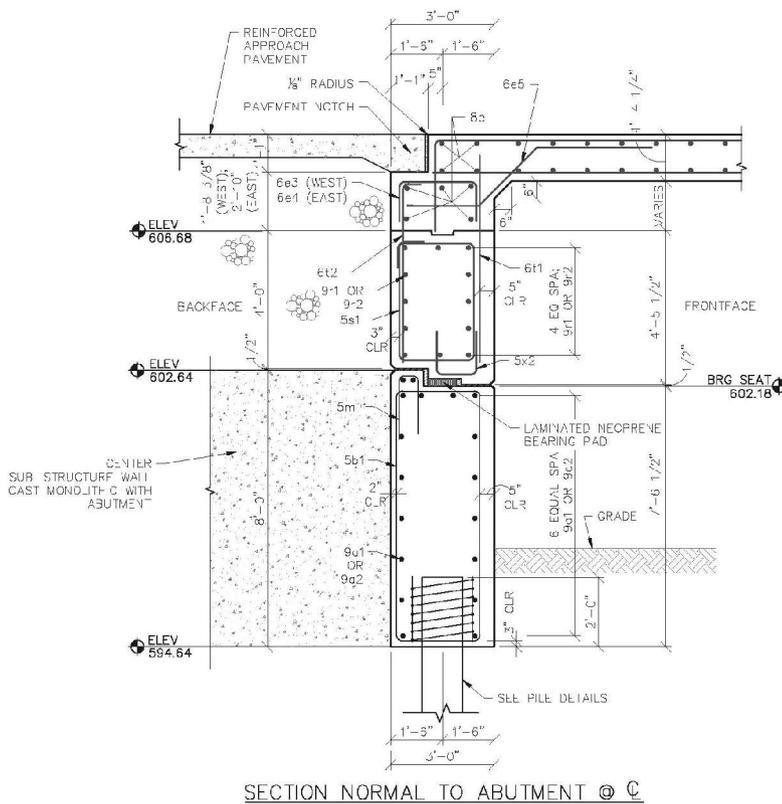
clearance for a multi-use recreational trail beneath one of the end spans. The bridge profile was based on the existing street profile due to limited approach lengths.

The superstructure cross section was influenced by multi-transportation modes and provided a gradual transition and fit to the two lane urban street.

The Rhomberg Avenue Bridge, one of four bridges making up the Bee Branch Creek Restoration project, is a 90- by 45-ft, 3-span (27.5-35-27.5 ft), 0° skew, continuous cast-in-place concrete slab bridge. The superstructure cross section was influenced by multi-transportation modes and provided a gradual transition and fit to the two lane urban street. A raised, cantilevered sidewalk was incorporated with an 8-in. curb adjacent to the bike lane and traffic corridor.

The gravity and lateral design parameters were based on the sixth edition of American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*, including HL-93 criteria and a future wearing surface. Flowing water velocities were relatively low at about 7 ft/s, primarily due to the low stream slope (0.5%).

Driven concrete-filled steel pipe (14 in. diameter by 0.375 in. thickness) displacement piles were utilized due to the depth to bedrock of



Rhomberg Avenue Bridge abutment detail.

three public workshops. The public workshops included visual preference exercises using photographs to illustrate bridge structure types, shapes, and materials. The Keystone Bridge, a historic stone arch bridge in Elkader, Iowa, was overwhelmingly recommended by the public.

As the design was developed, three-dimensional modeling and animation were utilized to help residents and the city visualize several alternatives, and detail the various project components. This provided an authentic

understanding of the project's impact, allowing for important input prior to finalizing the design.

Design Aspects

The geometry of the bridges for the Bee Branch Creek Restoration project was driven by their core purpose to provide vehicular and pedestrian passage over the waterway and storm water conveyance. The bridges over the Upper Bee Branch Creek span the flowing creek with approximately 16 ft of water surface elevation change while providing horizontal and vertical

CITY OF DUBUQUE, OWNER

PRIME CONSULTANT: Strand & Associates, Madison, Wis.

LANDSCAPE ARCHITECT: Ken Saiki Design, Madison, Wis.

GEOTECHNICAL ENGINEER: Allender Butzke Engineers, Urbandale, Iowa

BRIDGE DESCRIPTION: A 90- by 45-ft, 3-span (27.5-35-27.5 ft) 0° skew, continuous cast-in-place concrete slab

STRUCTURAL COMPONENTS: A 16¼-in.-thick reinforced cast-in-place concrete slab with 3-ft-thick abutments with expansion bearings, and pile bent fixed bearing piers with fully encased piles; six precast concrete arch façade panels coupled with cast-in-place decorative piers and curved planters incorporating formliners and multi-color stain; Texas classic crash tested barrier rail system and custom railing panels/light pole bases.

BRIDGE CONSTRUCTION COST: \$1,426,040 (includes substructure, superstructure, arch surface treatment, precast panels, railing, planters, and approaches)



Rhomberg Avenue Bridge creates a gateway experience.

approximately 200 ft, and presence of fine to coarse sands with standard penetration test (SPT) blows per foot ranging from about 10 to 15 through the majority of the driven pile length. The nominal axial bearing resistance for construction control was determined from a noncohesive soil classification and a geotechnical resistance factor of 0.55. The required nominal axial bearing resistance was 127 tons for the abutment piles, and 120 tons for the pier piles at the end of pile driving, which required a wave equation analysis for pile driving (WEAP) with bearing graph.

Pile bent fixed bearing piers (45 ft wide, 19 ft high, and 2 ft thick) with fully encased piles and a 3-ft-high pier cap were utilized to minimize debris accumulation and provide superior in-plane lateral load resistance. The pier height was driven by the “low flow” channel beneath the center span and calculated scour depths, placing the bottom of pier approximately 3.5 ft below the channel bottom.

High abutments were provided for stormwater conveyance and underpass trail clearance requiring a unique application of an integral slab/abutment with expansion bearing for the upper portion and creating cells integral with the planter substructure for the lower 8 ft of the abutment to resist lateral forces similar to a

deadman. An analysis was performed of the slab/abutment load transfer as well as a soil-structure interaction analysis on the deadman cells to determine reinforcing requirements.

The Upper Bee Branch Creek bridges were seen as an opportunity to create a gateway experience for travelers.

The Upper Bee Branch Creek bridges were seen as an opportunity to create a gateway experience for travelers at the street level and to send a message that they were entering something unique and special. This was the driving force behind incorporating planters with pedestrian viewing and seating areas and open railings. The bridge elevations required a high attention to detail, heavily influenced by strong, predominantly horizontal lines while recognizing the longitudinal street profile and adapting to the level lines of the formliners.

Creative application of a Texas Classic open barrier rail system and custom railing panels embossed with the street name were incorporated. A Test Level Two (TL-2) crash tested railing was selected based on a local street,

vehicle type/frequency, and design speed. Innovative precast concrete façade panel enhancements, to give the illusion of a series of limestone arches, were important features to satisfy the public workshop visual preferences. The precast concrete panels have gravity and lateral support at the substructure. Lateral support at the top is provided by the sidewalk, which cantilevers over the precast concrete panels to conceal and protect the top connection while maintaining independence for deflection and expansion/contraction.

Formliner selection and color were critical to emulate native Dubuque limestone. A 12 in. cut limestone pattern was used for support/base elements, while a smaller random ashlar pattern was selected for the precast concrete panels compatible with the massing. Since both cast-in-place and precast concrete elements were used, field application of a custom water-based multi-color stain was used to provide a consistent appearance. The barrier railing was coated with a solvent-based, single-color stain due to more aggressive service conditions of salt, moisture, and sunlight on the horizontal and vertical surfaces.

It was recognized the stain will require periodic maintenance. However the bridge service life will likely extend into the next century due to the durability of continuous concrete slabs, incorporation of Iowa Department of Transportation (IowaDOT) concrete mixtures, and utilization of epoxy-coated reinforcement.

Construction Sequencing

The Rhomberg Avenue Bridge was located within 50 ft of a historic structure. Therefore, vibration due to pile driving was a concern. A preconstruction analysis based on information from the National Highway Institute and the IowaDOT revealed peak particle velocities with the potential for damage to the existing structures to warrant a heightened monitoring protocol. This included a condition assessment, real-time vibration monitors, crack gauges, and survey monitoring. At completion of the bridge construction in the summer



Superstructure under construction.



Formliner used on inside and outside corners.

of 2016, no movements were detected nor any other adverse effects to the existing buildings.

The majority of the structure was designed and constructed as a typical IowaDOT continuous concrete slab bridge. The contractor was able to utilize their standard forms and falsework and complete the core substructure and superstructure elements efficiently.

Just as attention to detail was important in the design, it was even more important during construction. Careful selection of construction joint locations in the design were important to recognize the expansion/contraction requirements. Constructability, coupled with aesthetic considerations, influenced the field-approved construction joint locations. Irregular formliner surfaces required close attention to the quality of outside corners, and especially inside corners, which were more difficult.

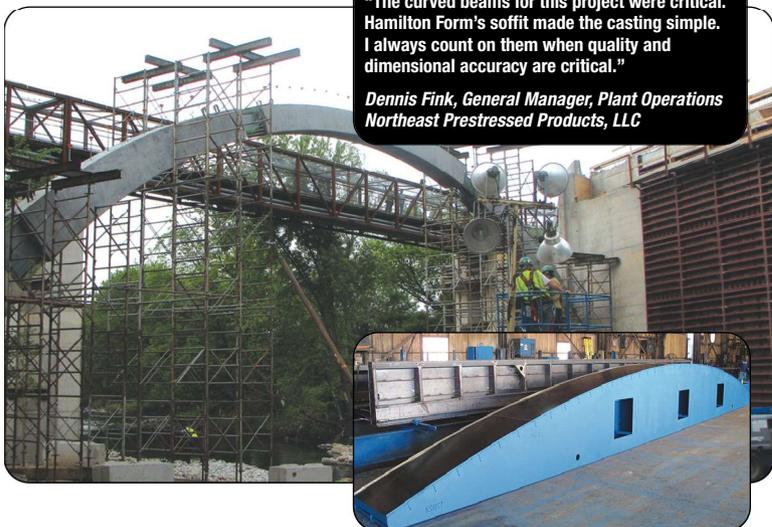
The Rhomberg Avenue Bridge was completed in the summer of 2016. This bridge, along with this entire urban revitalization project, is a superb example of understanding expectations, paying attention to detail, and collaborating to meet performance criteria and contribute to quality of life with the built environment. 

Michael A. Jansen is chief executive officer and principal civil & structural engineer at IIW P.C. in Dubuque, Iowa.

21 CASE STUDY

HAMILTON FORM CREATES FUNCTION

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*Dennis Fink, General Manager, Plant Operations
 Northeast Prestressed Products, LLC*

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Las Vegas Airport Interchange

New Mexico builds a bridge under a bridge to accelerate schedule

by Raymond M. Trujillo,
New Mexico Department of Transportation

Nearly complete bridge on Frontage Road 2142 to the Las Vegas, N.Mex., airport. Photo: Fernando Quiroga.

In New Mexico, many bridges carrying interstate traffic or local roads over interstates are reaching the end of their design and service lives. Due to increased traffic volumes and vehicle weights, many of these are considered functionally or structurally deficient. The state is methodically prioritizing and replacing these structures yearly.

In 2012, the bridge carrying frontage road (FR) 2142 over Interstate 25 (I-25) in Las Vegas, N.Mex., was determined to be structurally deficient and rapidly deteriorating. Replacement of this bridge, the Las Vegas Airport Interchange, became a priority for the District 4 office of the New Mexico Department of Transportation (NMDOT).

Background

The NMDOT engineers established the need to reduce the duration of construction and minimize inconvenience to the travelling public because closure of the bridge would

Methods Used to Accelerate and Accommodate Under-Bridge Construction

- Construction of abutments and piers under existing bridge
- Abutment excavations stabilized with retaining walls and soil nails
- Drilled, cast-in-place concrete micropiles
- Precast concrete abutment caps with back walls
- Precast concrete pier cap
- Precast concrete wingwalls
- Shallow adjacent precast concrete box girders
- Transverse post-tensioning
- Reduced thickness cast-in-place concrete composite deck that required no supporting formwork

require a 5-mile detour to access the airport. The existing alignment and profile grade were to be maintained to

eliminate the cost and time required for reconstruction of the approach roadway.

The bridge design engineer proposed replacing the existing five-span bridge with a two-span structure, placing the center pier between the two existing median shoulder piers. Early on, the NMDOT Bridge Design Bureau recommended incorporating accelerated bridge construction (ABC) techniques. For this bridge, a reduced closure could be accomplished by constructing the foundation and part of the substructure under the existing bridge while it remained in service. In addition, prefabricated bridge elements and systems (PBES) components would be used. NMDOT has had success with this method on previous bridge projects.

The new Las Vegas Airport Interchange Bridge is 170 ft long and 36.17 ft wide. It carries two, 12-ft-wide travel lanes and two, 4-ft 7-in.-wide shoulders plus 1-ft 6-in.-wide barrier rails.

profile

LAS VEGAS AIRPORT INTERCHANGE / LAS VEGAS, NEW MEXICO

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: Quiroga Pfeiffer Engineering Corporation (QPEC), Albuquerque, N.Mex.

PRIME CONTRACTOR: El Terrero Construction LLC, Rio Rancho, N.Mex.

PRECASTER: Coreslab Structures (ALBUQUERQUE) Inc., Albuquerque, N.Mex.—a PCI-certified producer

POST-TENSIONING CONTRACTOR: El Terrero Construction LLC, Rio Rancho, N.Mex.

Foundations

A spread footing was used at the pier. Since adequate space was not available for spread footings at the abutments, micropiles were selected on which a pile cap was cast to support the abutment walls. The existing fill slope at the abutments needed to be excavated in order to drill and cast the micropiles. During this construction, a temporary retaining wall was constructed and stabilized with soil nails.

Micropiles were selected for this bridge because they could be constructed under low headroom. NMDOT had not used them previously but construction was straightforward. An alluvial soil layer, 9.5 ft thick at abutment 1 and 6.5 ft thick at abutment 2, overlaid bedrock. A 7.5-in.-diameter hole was bored 15 ft into bedrock. A 7-in.-diameter steel casing was placed in the alluvial layer, extending 6 in. into the pile cap and 12 in. into bedrock. A neat cement grout with 4 ksi design compressive strength was tremied into the hole and around the casing. One no. 14 epoxy-coated Grade 75 reinforcing bar was inserted for the full depth. The bar extended 12 in. from the top of casing and was threaded with double nuts and washer plate to anchor it in the cap. The foundation required 17 vertical and 15 batter piles under each abutment and 14 vertical and 10 batter piles under each retaining wall that extends 37.5 ft from each side of both abutments.

Substructure

Substructures were built in two phases. The first phase included installing the micropiles and cast-in-place concrete construction for the abutment and retaining wall pile caps, the abutment walls, the spread footing at the pier, and the three pier columns.

After the first phase substructure components were constructed under the



The cast-in-place concrete pier columns and precast concrete pier cap are shown in the foreground with the cast-in-place concrete retaining and abutment walls with precast concrete abutment cap in the background. Photo: Fernando Quiroga.

existing bridge while still in service, the ABC-PBES strategy was implemented. The existing bridge was closed to traffic and demolished. The precast concrete abutment caps and pier cap were immediately set in place to complete the substructure.

The precast abutment caps are L-shaped, providing both the 2-ft-wide girder seat and a 1-ft-wide back wall. Overall, they are 3 ft wide and approximately 7 ft 3 in. high by 36 ft 6 in. long.

The precast concrete pier cap is rectangular in cross section, 4 ft 6 in. wide by approximately 4 ft 4 in. high, and 36 ft 6 in. long.

Both types of caps are connected to their supporting elements with grouted reinforcing bar splicers that fully develop the reinforcement across the joints. The abutment caps contain four groups of 10 no. 8 sleeves and the pier caps contain 10 no. 9 sleeves at each connection to a pier column.

Two additional precast concrete elements were used at each abutment.

Irregular-shaped wingwalls are approximately 9 ft 3 in. long by 7 ft high and 15 in. thick. Each wall was connected to the cast-in-place concrete abutment wall using 26 no. 8 grouted bar splicers.

Superstructure

Once the substructure was completed, nine NMDOT Type 39 precast, prestressed concrete adjacent box girders were erected on each of the two spans. The box girders are 39 in. deep and 48 in. wide by 84.5 ft long. The design concrete compressive strength was 9.5 ksi at 28 days and 7.0 ksi at prestress transfer. These girders allowed increased vertical clearance over I-25 and maintained the existing profile grade.

The box girders were transversely post-tensioned together in groups of three with single girder overlaps between groups. Two post-tensioning tendons were used at quarter points. The tendons were 1-in.-diameter, 150 ksi threaded bars inserted through 2¼-in.-diameter ducts except at the center girder where 3-in.-diameter ducts were used to accommodate the change in



After demolition of the existing bridge, the precast concrete abutment cap with back wall is placed on the abutment wall. The bar extensions will extend into the bar splice sleeves embedded in the precast concrete wingwalls. Photo: Fernando Quiroga.

NEW MEXICO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A two-span, adjacent box-girder bridge with span lengths of 85 ft on foundations and partial substructures that was built under an existing bridge in service to expedite the construction schedule

STRUCTURAL COMPONENTS: Eighteen, 39-in.-deep by 48-in.-wide, adjacent, precast, prestressed concrete box girders with a 5.5-in.-thick, composite, cast-in-place concrete deck; precast concrete pier cap on cast-in-place concrete columns on spread footing; precast concrete abutment caps on cast-in-place concrete abutment walls and retaining walls supported by pile caps on drilled, cast-in-place concrete micropiles; precast concrete wingwalls

BRIDGE CONSTRUCTION COST: \$1,757,114; \$282 per sq. ft.

AWARDS: 2015 PCI Design Award for Best Bridge with a Main Span from 76 to 149 ft; 2015 Excellence in Concrete Award by ACI New Mexico chapter



The cast-in-place concrete pier columns are complete and await demolition of the existing bridge. Photo: Fernando Quiroga.

trajectory, considering the center girder was placed level and the girders on each side were set with a 2% down slope. The girders were post-tensioned prior to grouting the shear keys using load-indicating washers to establish the necessary forces in the bars.

Shear key grout was required to be prepackaged commercial material and attain compressive strength of 6 ksi. Prior to grouting, the girder shear keys were required to be saturated, surface dry after a 24-hour wetting period. After the grout was rodded into the shear keys, it was required to be water cured for 72 hours.

A 5.5-in.-thick concrete deck was placed on top of the box girders to provide a wearing surface and to distribute live loads.

Phasing and Traffic Control

Single lane closures on I-25 were required at times when equipment needed to be located adjacent to traffic, when bridge demolition occurred, and

when precast concrete elements were lifted into place. Crossovers were built to switch traffic to one side when the work needed to be located over the travel lanes. The adjacent box girders provided a safe work platform for deck construction and only required edge forms for the cast-in-place concrete deck.

Summary

Although ABC methods have been used by NMDOT on earlier bridge projects, ABC methods are not commonly used. This project reaffirms the department's willingness to use ABC methods when they will benefit the traveling public.

The ingenuity of this bridge replacement was combining cast-in-place concrete with PBES elements to expedite construction during the critical 45-calendar-day bridge closure. It should be noted the demolition of the existing bridge, the completion of the substructure, and construction of the superstructure were all accomplished in 1 week. The contractor elected to use the full 45 days to complete the deck cast, construction of bridge railing, the approach slabs, approach roadway tie-in, and painting of the bridge.

The precast concrete elements were produced in a local fabricator's yard so formwork and reinforcement layout were readily accessible for inspection. This provided better control of the materials and tighter dimensional tolerances required for fit-up, especially considering the jobsite extension of dowels to mate with splicing sleeves in the precast concrete components.



Drilling for micropiles proceeds under the shadow of the existing bridge. The single no. 14 reinforcing bar in each pile is supported on the top of the steel casing. The temporary soil-nailed retaining wall is in the background. Photo: Fernando Quiroga.

The project was very positively received by all involved. The project manager stated, "This was a great design and an excellent contractor to work with." District 4 was pleased with the work and made a presentation of the project at the NMDOT Engineering Conference. The project received a PCI Design Award as well as an award from the New Mexico chapter of the American Concrete Institute. 

Raymond M. Trujillo is the chief of the Bridge Design Bureau with the New Mexico Department of Transportation in Santa Fe, N.Mex.



A substantial portion of construction of the cast-in-place abutment and retaining walls was completed while the existing bridge remained in service. Photo: Tom Cartner.



Color combined with the simple, well-balanced lines of the new Las Vegas, N.Mex., Airport Road Bridge have enhanced the driver experience on Interstate 25. Photo: Fernando Quiroga.

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Certification Assurance

Certification standards vary for materials and techniques, requiring designers to look beneath the surface to be assured they are getting what they expect

by Craig A. Shutt

To help ensure products and materials will meet the standards of quality and precision they require, designers often look to industry certification programs to provide reassurance. But how stringent are certification bodies and do they provide the assurances the designers expect?

The Precast/Prestressed Concrete Institute (PCI) recently addressed these questions by going through the process to receive accreditation from the International Accreditation Service (IAS) for the PCI quality assurance manuals and the procedures that PCI-certified plants use to produce precast concrete products. IAS has accredited PCI's Plant Certification Program, which now is managed in accordance with IAS Accreditation Criteria (AC) 477 and ISO/IEC 17021, *Conformity Assessment—Requirements for Bodies Providing Audits and Certification of Management Systems*.

'IAS provides objective evidence that an organization operates at the highest level of ethical, legal, and technical standards.'

According to the IAS website, "IAS provides objective evidence that an organization operates at the highest level of ethical, legal, and technical standards." The group is a subsidiary of the International Code Council (ICC), which develops the building, energy, fire, mechanical, plumbing, and other codes used by most U.S. municipalities. The three driving tenets of the accreditation are: competency, confidentiality, and impartiality.



IAS is a nonprofit, public-benefit corporation providing accreditation services since 1975. As a subsidiary of ICC, it accredits a range of companies and organizations, including governmental entities, commercial businesses, and professional associations. It acts like a registrar and has more than 900 accredited entities worldwide. IAS accreditation is based on recognized national and international standards that ensure domestic and global acceptance of its accreditations.

Who Certifies the Certifiers?

In such certification programs, the credibility of the certifying body is critical. Bridge engineers may not be as familiar with building-component certifying bodies such as IAS and ICC, and thus may require assurances that these bodies provide the same rigors for transportation material as they do in the building arena. For these assurances, engineers turn to the International Organization of Standardization (ISO).

The key element in determining an equivalency is to find a base of standards recognized by each industry to ensure they are rigorous on the significant required points. In the case of IAS, the organization follows all standards and requirements laid out by ISO supported by American National

Standards accredited by the American National Standards Institute (ANSI). It is important to note that PCI is an ANSI-accredited standards developer.

This base of standards allows IAS certification to be applied to materials in accordance with those recognized certification authorities. Some states provide this equivalency in their programs. The Florida Building Commission, for instance, through its Florida Administrative Code Rule 9B-72, allows products to be deemed certified only if the products' certification agency is "accredited by ANSI [to] meet the requirements of ISO/IEC Guide 65: *General Requirements for Bodies Operating Product Certification Systems* or other standard certified as equivalent."

Rule 9B-72 also requires quality-assurance agencies to annually audit the manufacturer's quality-assurance program through in-plant visits, product inspections at sites or distribution facilities, or testing of production-line samples. These elements are part of the IAS program, based on American National Standards, and are part of the PCI program.

By and large, the PCI quality-assurance program already provided these elements. With slight modification, these elements were brought into conformity with IAS and ISO requirements and certifying standards overall, which is a detailed process requiring significant documentation and added training and assessment activities.

"Our goal in attaining IAS accreditation was to ensure all processes associated with PCI's certified quality-management system fall in line with internationally accepted best practices and to ensure continuous improvement of the PCI

Research, Documentation Underlie Best Programs

Research produced and openly disseminated by long-standing technical institutes, which fund and monitor ongoing studies and programs of all types, often serve as the basis for the creation of alternative, static, low-cost, checklist-based programs run by trade associations and for-profit organizations.

This is why code organizations turn to technical institutes when developing their own standards, as the institutes are the source of the critical research that underlies the procedures. For instance, the codification and calibration of the AASHTO LRFD Bridge Design, Construction, and Rating Specifications for fabricated bridge elements relied upon the standards, publications, practices, and personnel certifications noted below, all promulgated by technical institutes:

-  American Iron and Steel Institute (AISI) plate standards;
-  AISC for best practices and plant certification;
-  American Segmental Bridge Institute (ASBI) for best practices and grouting-personnel certification;
-  American Concrete Institute (ACI) for best practices and personnel certification;
-  ASTM International for materials and test standards;
-  American Welding Society (AWS) structural welding code, after-welding distortion tolerances, best practices, and personnel certification;
-  Concrete Reinforcing Steel Institute (CRSI) reinforcement dimensions, bending and placement standards, and epoxy coating plant certification;
-  PCI for best practices, plant certification, and personnel certification; and
-  Post-Tensioning Institute (PTI) for best practices, hardware standards, and personnel certification.

This figure originally appeared in the Fall 2009 issue of ASPIRE.

Plant Certification program,” explains Dean A. Frank, PCI director of quality programs.

Many Benefits Result

PCI sought to achieve multiple goals with IAS accreditation. They include:

- Ensuring all processes associated with the quality-management process fall in line with internationally accepted best practices
- Providing a tool to ensure continuous improvement of the PCI Plant Certification Program
- Maintaining and increasing credibility with design professionals, code officials, and authorities having jurisdiction
- Providing objective evidence of PCI’s commitment to providing top-quality certification programs
- Assuring specifiers that PCI-Certified Plants can manufacture engineered-to-order and complex structural and nonstructural elements as designed
- Showing that PCI’s plants operate at the highest level of ethical, legal, and technical standards
- Offering credentials to ensure PCI Plant Certification will be accepted in the marketplace and by governmental agencies that regulate service or product acceptance

- Aligning more closely with ICC and enhancing the program’s standing with various building departments and authorities having jurisdiction
- Increasing credibility of the PCI Plant Certification Program on an international level

The program addresses any real or perceived conflicts of interest in having PCI-retained personnel performing certification audits for the plants, Frank explains. It provides an outside, credible source to review performance and standards that is accepted worldwide. “It is not just a club that meets its own easily achieved standards,” he says.

Customer Satisfaction Process

A key element for owners, designers, and contractors is the customer satisfaction process. This system ensures complaints about quality or other aspects of the products can be officially filed with the PCI Director of Quality Programs, who then coordinates with the plant to give additional incentive for the plant to resolve the issues. To facilitate any questions, a Feedback page has been added to the PCI website. It contains forms that can be filled out and submitted to PCI quickly.

IAS accreditation offers added assurance to the construction team that quality standards have the highest probability of being met and ensures consistency among PCI-certified

plants. “IAS accreditation provides independent verification that the program’s procedures appropriately address competency, confidentiality, and impartiality,” says Frank. “It should go a long way in easing the minds of the construction team.”

Designers recognize that materials and products manufactured by a plant certified by an accredited management system certification body, such as PCI, offer the best level of quality assurance. Certification programs that follow these rigorous standards produce the consistent, precise levels of quality that owners and designers expect when they specify products. 

EDITOR’S NOTE

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For more information, see the paper in the Fall 2009 issue of ASPIRE on the Institute Certification, and the white paper located at www.pci.org/uploadedFiles/Siteroot/PCI_Certification/Related_Content/Related_Content_Files/AISC_PCI_Quality_Systems_White_Paper.pdf

FHWA Publishes Reinforcing Steel Practice Timeline

by Dr. Danielle D. Kleinhans, Epoxy Interest Group of the Concrete Reinforcing Steel Institute



The effort to create the reinforcing steel practice timeline was conducted as part of the Federal Highway Administration's (FHWA) Long-Term Bridge Performance (LTBP) Program. The LTBP Program is a minimum 20-year research effort to collect scientific performance field data from a representative sample of bridges nationwide that will help the bridge community better understand bridge deterioration and performance. The products from this program will be a collection of data-driven tools including predictive and forecasting models that will enhance the abilities of bridge owners to optimize their management.

The first of the material timelines, titled "FHWA LTBP Summary—National Changes in Bridge Practices for Reinforcing Bars," has been published and outlines the changes in reinforcing steel practice and specifications from 1910 through 2015. Further summaries on cement and concrete additive materials have been proposed.

The FHWA and their contractors for the LTBP Program continue studying and collecting field data from bridges constructed since 1960. Comparisons between the bridges will be made from the data. However, all involved recognize that technology has changed significantly over the past 50+ years, in

particular, the materials that are used for bridge construction. The FHWA reached out to industry, specifically the National Concrete Bridge Council (NCBC), to better understand important developments in various steel-reinforced concrete bridge materials.

The Need for Corrosion Protection

Bridges in much of the United States are subjected to deicing chemicals during the winter months, and bridges located in a marine environment are subjected to seawater. Many deicing chemicals contain chloride ions. As snow and ice melt, water carries these chloride ions down into the pores of the concrete surface. When present in sufficient concentrations, chloride ions cause the reinforcing steel to exfoliate, causing stress within the hardened concrete. As the rust expands, it cracks the concrete, and a spall can develop adjacent to the corroded steel reinforcement.

Specialty reinforcing bars were developed to address issues related to corrosion or to provide increased tensile strength. The types of specialty-reinforcing bars include epoxy-coated, galvanized, dual-coated, low carbon-

chromium, and stainless steel. The timeline calls out the development dates of U.S. reinforcing bar specifications published through ASTM International and the American Association of State Highway and Transportation Officials (AASHTO). Reference is also made to several improvements to quality initiated by industry within the epoxy-coated reinforcement specifications.

The "FHWA LTBP Summary—National Changes in Bridge Practices for Reinforcing Bars" can be found on FHWA's website at: <https://www.fhwa.dot.gov/publications/research/infrastructure/structures/ltpb/16012/index.cfm>. **A**

Dr. Danielle D. Kleinhans is the managing director of the Epoxy Interest Group (EIG) of the Concrete Reinforcing Steel Institute (CRSI) in Schaumburg, Ill.

EDITOR'S NOTE

The author acknowledges Susan Lane with the Federal Highway Administration for her contributions to this article.

1989	<p>ASTM revised standard A775/A775M in the following ways^(20,53).</p> <ul style="list-style-type: none"> • Changed the damage threshold value of the total surface area in each 1-ft length of bar from 2 to 1 percent. • Introduced an "anchor profile" which is a measure of surface roughness after blast cleaning and prior to coating. Measures for anchor profile include maximum peak height and exposed surface.
1990	<p>ASTM revised standard A775/A775M to include a provision that states that all damage to the epoxy coating incurred prior to the shipment of rebars to the job site must be repaired.^(21,52,53)</p> <p>FHWA issued a memorandum on certification programs that encouraged owner agencies to require certification of producers involved in federally funded projects and specifically named the CRSI's upcoming Epoxy Coating Applicator Plant Certification Program.⁽²²⁾</p>
1991	<p>CRSI began a voluntary certification program for epoxy-coating applicator plants.⁽⁵²⁾</p>

Example Timeline Entries.

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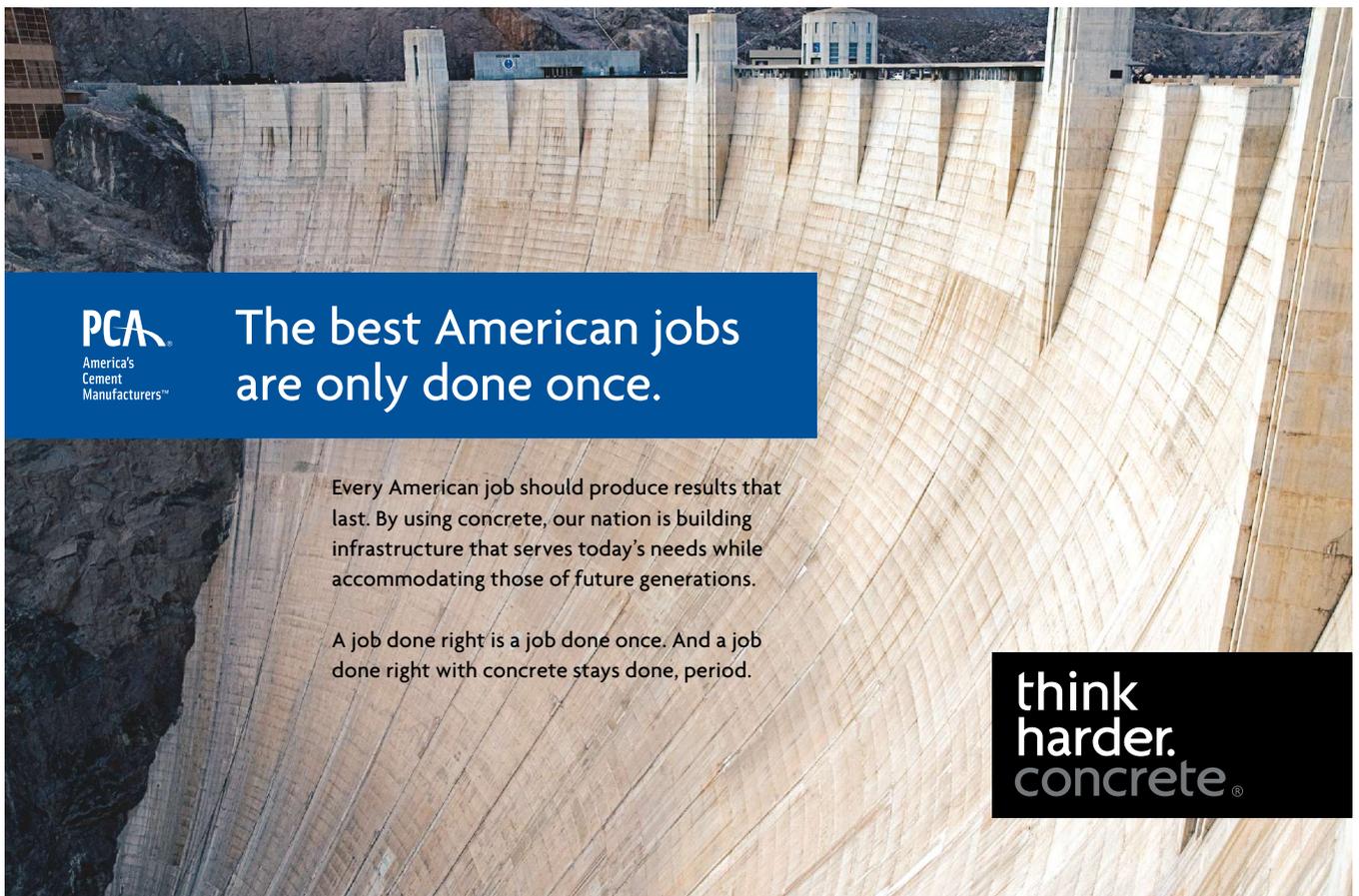
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Durability of Post-Tensioning Systems: The Details Matter

by Timothy Barry, RS&H

Today's post-tensioning (PT) industry is facing scrutiny due to performance issue on projects that have been deemed to be in violation of project specifications. In some locations, owners are questioning the viability of post-tensioning rather than investigating root causes and implementing improved procedures. With proper planning and execution, however, the industry has repeatedly shown that any PT project can be successful by implementing quality specifications, using quality materials, and performing the work the right way. Attention to detail matters during these operations, and it has been proven time and time again that shortcuts can lead to major problems.

Preconstruction Commitment

Like all construction projects, success depends on the level of engagement of all stakeholders. This starts with the owner and designer instituting the right specifications for the project. The PT industry has developed effective specifications over a number of years to account for many lessons learned. The Post-Tensioning Institute's (PTI's) and American Segmental Bridge Institute's (ASBI's) *PTI/ASBI M50.3-12 Guide Specification for Post-Tensioning* and the *PTI M55.1-12: Specification for Grouting of Post-Tensioned Structures* are examples of valuable resources providing owners a comprehensive specification that can lead to a quality final product.

These specifications provide a starting point for owners and have proven to be effective through years of use. In these specifications are various personnel requirements for years of experience and specific training. These requirements, already implemented on numerous projects, have proven to be an effective way to achieve the desired construction quality. Owners should enforce similar requirements for inspection staff as well. The owner should have their own expertise, which is equally qualified, and that is looking out for the owner's long-term



Grout mixing operations. All Photos: RS&H.

interests. Understanding the specifications and their specific intent goes a long way toward institutionalizing quality through construction.

Grouting Operations

A diligent commitment to proper grouting procedures has been shown to be one of the most effective ways to alleviate durability issues. The current PT industry specifications, when used properly, have proven to be very effective in achieving fully grouted tendons. All parties need to understand that there can be no shortcuts or missed steps when it comes to grouting procedures. This includes buy-in from the contractor's personnel and the inspection staff at all levels of the project. This buy-in starts with the respective project managers from the contractor and the owner creating this culture of high-quality construction. It should be understood from the top that commitment to quality and adherence to proper procedures are expected.

Inspection oversight of grouting operations has become one of the most important jobs in the PT industry. There have been too many examples where flawed inspection, or simply lack of inspection, was noted on projects that experienced problems with tendon durability. No part of the grouting

operation can be overlooked and strict adherence to procedures is the key. Like many things in life, preparation ahead of time improves the potential for success. For PT grouting, preparations include knowing the storage condition of the grout, tracking the expiration dates of the grout, and establishing the proper water-cement ratio, exact batch parameters, theoretical volume for the day's operation, efflux testing of the mixed grout, unit weight of the mixed grout, inlet and outlet locations, and the sequence of operations. These are all items of information that can and should be determined long before the first batch of grout is mixed.

Everyone involved in the grouting process must be aware of the details in the project specifications. Without exception, these details must be understood and followed explicitly. This translates directly to the project specific grouting plan that will be developed and approved to achieve the owner's expectations. Development of the plan should address batching parameters, equipment, grouting sequence, methods of maintaining proper grouting pressures, material testing, and observation of the operations. This plan is also a way for the contractor to consider ahead of time how these important details will be handled.



Unit weight testing of grout by mud balance.

Determination of “good grout” in the field is important for knowing when a PT tendon is complete and full. Constant material testing throughout the process is imperative. Testing for bleed water for all grout batches mixed should be performed. There should be careful control of mixing procedures so they do not deviate from specified practices. Monitoring mixture temperatures and checking efflux values are important ways to ensure control of the grout material as it is being batched and pumped. During grouting operations, grout quality is monitored and maintained using the unit weight determined by a mud balance and the efflux rate determined by a flow cone.

The grout should be tested prior to pumping into the inlet with the unit weight and efflux rate recorded. At the grout outlet, the material is tested again and the results must compare favorably or grout must continue to be pumped. It is at this stage that convenience or schedule cannot override the need for assurance of quality material. The ultimate goal for all of these steps is a fully grouted PT tendon with properly mixed grout. Attention to detail and commitment to the process will go a long way towards that goal.

Post-Grouting Inspection

The final step in the process is visual inspection of the grouted PT tendons. Post-grouting inspection should be performed for all grouting operations, regardless of the size of the project or the scope of the operations. Visual inspection and sounding of PT tendons are two ways to quickly identify issues and provide a means to effectively address any issues before they can have long-term effects on the structure. If identified immediately, the contractor can remedy any voids discovered and eliminate the problem prior to the completion of construction. This final procedure provides the owner



Flow cone testing of grout.

an additional level of assurance that grouting operations were successful. Visual inspection should not be overlooked or skipped as it is an integral part of the process for successful grouting operations.



Post-grouting visual inspection using a borescope.

Moving Forward

Grouting of PT tendons remains among the most important aspect of PT construction. It also remains one of the most scrutinized practices in the PT industry. The number of improvements the PT industry has made over the past 20 years is far too numerous to name here and the industry continues to head in the right direction.

At the most basic level, quality of the graded product will always be a reflection of the quality of the construction. Therefore, it is incumbent upon the PT industry to make sure these improvements are being executed to their fullest extent by strict adherence to the details and proper oversight of the construction. We have seen time and time again that even minor deviations from proper procedures can greatly impact the final product. Commitment by all parties, including the owner, designers, inspectors, and contractors, to doing things the right way will assure that the PT industry will perform in compliance with its outstanding publications, testing procedures, and certification programs. 

Timothy Barry is the Virginia-East regional leader for RS&H in Virginia Beach, Va.



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The Quality Partnership: Ensuring the Performance and Reliability of Post-Tensioning Installation and Grouting

by Theodore L. Neff, Post-Tensioning Institute

Concerns are being raised about post-tensioning (PT) grouting and installation, even though the majority of PT bridges worldwide are performing well and without problems. Why then the concern?

Several highly publicized problems have focused attention on PT bridge construction, and particularly on grouting. While actual cases of poor grouting are very few in number, these problems have shown that quality has not always been achieved and better reliability is needed.

Quality and Reliability

In an ideal world, everyone on the project team would share responsibility and ensure that everything is done right and with the highest quality possible. But as experience has shown in all aspects of construction, "stuff" happens. Whether it be from inattention, ignorance, inexperience, neglect, competitive pressures or simply bad luck, things do not always go according to plan.

Identifying Problems and Ensuring Quality Construction

Recognizing that some problems are inevitable, it is critical that appropriate controls are in place to ensure that these situations are identified and appropriate corrective/preventive actions are taken in a timely manner. To do so effectively requires the following:

- Good plans, specifications, and project details
- Quality control by the contractor and all of its subcontractors and suppliers
- Quality assurance by the owner or specifier
- Education and training of all personnel involved in the construction process

All are needed to consistently achieve a high degree of reliability.

Plans, Specifications, and Details

Plans, specifications, and details are typically the responsibility of the owner's engineer. Suitable plans and details greatly impact constructability and are the foundation for achieving quality. Poor details, such as improper location of grout inlets and outlets, may lead to voids and difficulty in completely filling a duct with grout. Furthermore, effective specifications "set the bar" for quality and ensure that the owner's performance and reliability objectives are met. Alternatively, lax specifications may put contractors, who are trying to do a good job, at a competitive disadvantage, and entice them to a hurried schedule without properly controlled processes to stay competitive.

Effective specifications "set the bar" for quality.

Contractor Quality Control

The contractor must have adequate quality control (QC) measures in place to ensure that the completed construction meets the owner's requirements as detailed in the plans, specifications, and other contract documents. This responsibility also applies to all of the suppliers and subcontractors on the project.

Often materials and products are pre-approved through ASTM testing or a qualification program before the project begins. However, as was learned the hard way with prepackaged grout in the PT industry, it is important that manufacturers have an ongoing QC program to ensure that their materials and products continue to meet project requirements throughout production and not just during initial qualification.

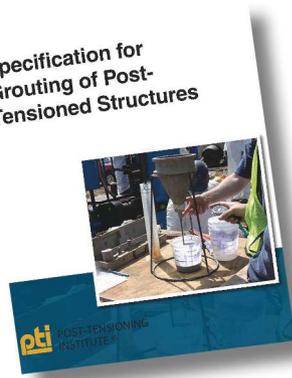
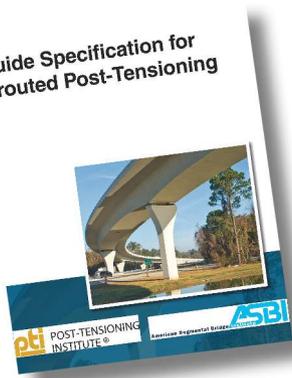
It is important that manufacturers have an ongoing QC program to ensure that their materials and products continue to meet project requirements.

Contractor QC must take into account the coordination and interaction of different subcontractors and operations that impact quality of the post-tensioning construction. If left solely to a subcontractor, there are often factors that are beyond the subcontractor's control. For example, reinforcement conflicts or misaligned ducts in precast concrete elements can lead to difficulties in PT installation and subsequent grouting. In these cases, the PT installation subcontractor is responsible for installation and grouting but may not have any control over the quality of other subcontractors' operations. The contractor's oversight and jobsite testing (for example, flow cone, density, and pressure testing) at critical points is essential to ensuring the quality of subcontractor work.

Owner's Quality Assurance

Quality assurance (QA) is normally the responsibility of the owner or its representative. Acceptance testing and related payment items are keys to a successful QA program. Enforcement of specification requirements is vital to achieving quality on the immediate job, as well as future projects.

Timely inspection of PT installation and grouting before a contractor leaves a jobsite generally means that corrective action, when necessary, will be easier than later when the structure is in service. For example, inspecting tendons shortly after grouting will identify voids, if any, that can be filled using vacuum grouting techniques while the grouting crew is still onsite. Furthermore, when problems are discovered early and a contractor must correct errors before being paid, it serves as a powerful economic incentive to do it right in the first place.



Keys to maximizing quality of PT installation

- Train personnel.
- Use standard specifications and details.
- Require contractor/supplier quality control.
- Require acceptance testing and inspection.
- Enforce contract requirements.
- Identify problems and take timely corrective action.
- Communicate.

Education and Training

Qualified personnel are the “grease” that makes the construction process run smoothly. Having installers who know what they are doing, designers who are familiar with PT construction and related details, and inspectors who know what to look for and why, are essential to achieving quality with a high level of reliability.

PTI Quality Efforts

The mission of the Post-Tensioning Institute (PTI) is to promote quality and advance the state-of-the-art of post-tensioned concrete design and construction. PTI has several activities that are intended to enhance quality of PT installation, including the following.

Standards and Specifications

The joint *PTI/ASBI M50.3-12: Guide Specification for Grouted Post-Tensioning* and the *PTI M55.1-12: Specification for Grouting of Post-Tensioned Structures* provide consensus-based standards that represent the latest state-of-the-art in PT bridge construction. These specifications are being continually updated by PTI’s technical committees, with membership representation from industry, academia, and owners. In addition, PTI is developing a new program to evaluate and qualify multistrand and bar PT systems. Updated editions of both specifications as well as the launch of the PT System Qualification Program are expected in early 2017.

Education and Training

PTI and ASBI certification programs provide education and training for field personnel. The existing PTI Bonded PT Field Installation and the ASBI Grouting Certification courses provide in-depth training on installation and grouting of PT tendons. A new companion program focused on inspection of bonded PT systems is being developed by PTI and will be available in early 2017.

Once in place, it is planned that a provision be added to the M-50 specification which would require a contractor to hire a certified third party inspector to oversee PT installation and grouting QC unless waived by the owner. This self-policing requirement would greatly strengthen contractor QC and minimize problems that go undetected and uncorrected.

Research

In 2017, PTI will sponsor research with a two-fold objective:

- First, study the suitability of using cement that meets the American Petroleum Institute’s API 10-A, *Specification for Cements and Materials for Well Cementing*, as PT grout. API well cements are produced to a much tighter specification standard with frequent QC testing, which may lead to reduced variability and improved reliability.
- The second phase of the study will be to evaluate the effectiveness and accuracy of in-line density meters in PT grouting. Automatic in-line density meters are widely used to monitor soil slurries, and have the potential to provide continuous, real-time monitoring of water content in PT grout.

Summary

Experience has shown that perfection in construction quality is probably not possible, but our goal should be to come as close as possible and realize a degree of reliability consistent with the owner’s needs. With a team approach where all parties—the PT installer, the general contractor and related subcontractors, the designer and the owner—take responsibility to pursue and achieve quality, a high degree of reliability and performance is not only possible, but likely. 

Theodore L. Neff is the executive director of the Post-Tensioning Institute in Farmington Hills, Mich.

Implementation of Flexible Filler for Post-Tensioning Corrosion Protection in Florida

by William R. Cox, American Segmental Bridge Institute

On January 28, 2015, the Florida Department of Transportation (FDOT) issued Structures Design Bulletin 15-01, "Update to Revisions to Policy for Post-Tensioning Tendons," mandating the use of flexible filler, in lieu of cementitious grout, for corrosion protection of certain post-tensioning (PT) tendons for projects under design beginning in 2015. Currently, the only FDOT-approved flexible fillers are microcrystalline petroleum-based waxes that are heated until liquid then injected to fill the PT tendon duct, providing long-term corrosion protection of the PT tendons. When flexible fillers are used, the PT tendons are designed to be unbonded and fully replaceable. Table 1 shows the required corrosion protection materials for post-tensioned tendon types in Florida.

Flexible fillers are to be installed under the direct supervision of a filler injection foreman and performed by grouting technicians in the presence of a filler injection quality control inspector. Each of these personnel is required to have

Table 1. Required corrosion protection materials by post-tensioning tendon type	
Tendon Type	Filler Material
Top slab cantilever longitudinal tendons in segmental box girders	Grout
Top slab transverse tendons in segmental box girders	Grout
Top slab transverse tendons in segmental box girders	Grout
Straight strand or parallel wire tendons in U-beams and girders	Flexible Filler or Grout
Bar tendons (predominately vertical or horizontal)	Flexible Filler or Grout
All other tendon types	Flexible Filler

an American Segmental Bridge Institute (ASBI) Flexible Filler Certification. Verifiable experience performing injection of similar flexible filler on at least two projects is currently acceptable in lieu of ASBI certification. However, this allowance will be deleted from the FDOT specifications after the first ASBI Flexible Filler Certification Training Course has been given.

involved with upcoming PT projects in Florida. As a prerequisite to attend the course, participants must hold current certificates as an ASBI Grouting Technician and a PTI Bonded PT Field Specialist. The course will consist of 8 hours of classroom instruction, 3 hours of laboratory demonstrations, and an exam. The course will cover all phases of flexible filler field installation. 

ASBI, FDOT, and the Post-Tensioning Institute (PTI) are sponsoring the first ASBI Flexible Filler Certification Training Course on May 9-10, 2017.

ASBI, FDOT, and the Post-Tensioning Institute (PTI) are sponsoring the first ASBI Flexible Filler Certification Training Course on May 9-10, 2017, in Tallahassee, Fla. This course is available to foremen, technicians, and inspectors

Randy Cox is the executive director of the American Segmental Bridge Institute in Buda, Tex.



Flexible filler encapsulation of post-tensioning wedge plate (grout cap removed). Photo: Florida Department of Transportation.

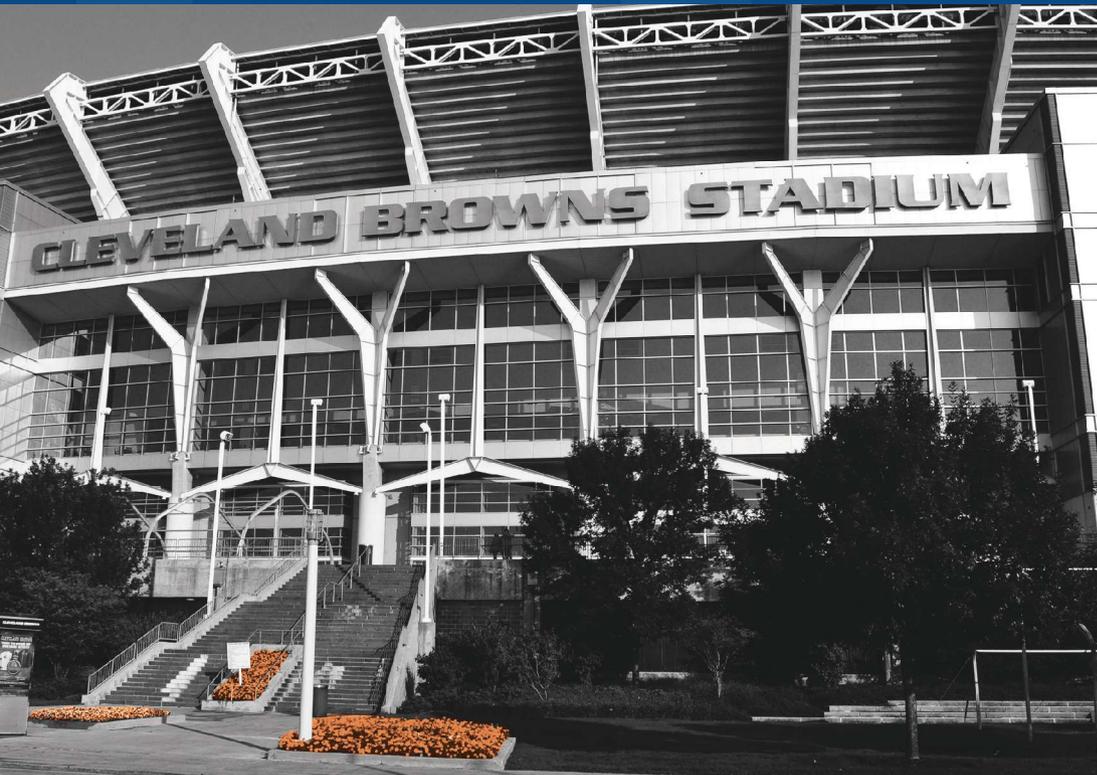
EDITOR'S NOTE

For information regarding the requirements for the use of flexible fillers on Florida Department of Transportation projects, see the FDOT Structures Manual: <http://www.fdot.gov/structures/StructuresManual/CurrentRelease/StructuresManual.shtm>.

For information regarding the ASBI Flexible Filler Certification Training, see <http://www.asbi-assoc.org/index.cfm/events/upcoming-events>.



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STRUT-AND-TIE MODEL

How did we get here and where do we go next?

by Dr. Oguzhan Bayrak, University of Texas at Austin

Since the strut-and-tie model (STM) originated in Europe in 1899, much has happened in the way of developing and refining this technique. Benefiting from about a century's worth of development, the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* included its first set of STM design provisions for bridge elements in 1994. *Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (ACI 318R-02)* included its first STM design guidance as an appendix to the code in 2002. It was not until 2007 that the use of the AASHTO LRFD specifications were mandated for use in federally-funded projects.

With much to learn from our European colleagues and their century-old experience with STM, several efforts in the United States took place to develop design guidance on STM. For example, the National Cooperative Highway Research Program (NCHRP) recently funded two 20-07 projects: Task No. 217 to develop design examples and Task No. 306 to offer improved guidance. Subcommittee A of ACI's Committee 445 prepared two special publications (SP-208, *Examples for the Design of Structural Concrete with Strut-and-Tie Models*, and SP-273, *Further Examples for the Design of Structural Concrete with Strut-and-Tie Models*). The Portland Cement Association also published an STM guidance document entitled *AASHTO LRFD Strut-and-Tie Model Design Examples* in 2004.

Within the context described previously, Ferguson Structural Engineering Laboratory (FSEL) researchers started their investigations toward the use and further development of this technique in 2002. Over the span of 12 years, and largely funded by the Texas Department of

Transportation (TxDOT), a team of researchers remained steadfast in their quest to improve the understanding of STM. During this period, FSEL researchers mined data from nearly all research projects conducted in the twentieth century, augmented knowledge by testing some of the largest test specimens in history, and improved our knowledge of STM. Four research projects, five doctorate students, six master's students, and 21 undergraduate students contributed to this development effort that ended in 2013. Equally important, nine staff members of FSEL were instrumental in supporting this ambitious multi-faceted project. This culminated in the STM design provisions developed at the University of Texas that are included in the reorganized Section 5 of the *AASHTO LRFD Bridge Design Specifications*, which will be published in 2017.

Many students who contributed to this effort are currently practicing or teaching structural and bridge engineering in Arizona, California, Washington, Indiana, Illinois, Texas, Massachusetts, Colorado, and Florida. Internationally, some have moved on to practicing and teaching in Mexico, Panama, and France. The human-resource-development aspect of the STM projects is equally as important as the technical objectives and this fact has to be recognized in view of the credit that has to be distributed to many brilliant minds. In summary, this is what AASHTO codified as the STM provisions in the latest *AASHTO LRFD Bridge Design Specifications*.

The 7th edition of the *AASHTO LRFD Bridge Design Specifications*, specifically the 2015 Interim Revisions, emphasizes the delineation of D-Regions from B-Regions and recommends the use of STM for D-Regions. For all practical purposes, the design of a great majority of substructure components will be done through STM. That is, the empirical/legacy methods will gradually retire and make way for designs by STM in the upcoming years.

Embracing this change quickly will pay dividends and will help produce better-performing bridge substructures. Like all change, there will be challenges that the bridge design community will face and addressing those challenges will certainly be possible. None of those challenges will be greater than the overall reluctance that many engineers possess for change. After all, we have been designing bridges for quite some time by using the legacy design methods.

As the thinking goes, at some level, all of us feel that "if ain't broke, don't fix it." The fact is, certain aspects of the legacy designs were "broke" and thus we really needed to "fix it." Those of us who leave our offices to take a look at the performance issues encountered in some bridges know all too well that some inverted-tee straddle bents and some hammer heads supporting reasonably long spans have some performance issues we do not commonly encounter in other bridge components. So, the notion that everything is just perfect and things cannot possibly be improved is open for debate.

All of us have to remember that shrinking resources drive the necessity to do more with less. To me, that is another way of stating that we need to improve our efficiency and the precision with which we design. The Precast/Prestressed Concrete Institute (PCI), among other organizations, has been emphasizing sustainability and efficiency. What better way to do that than to remove excess fat in our designs while adding additional design margin where we need it.



One of many full-scale specimens tested at Ferguson Structural Engineering Laboratory at the University of Texas at Austin. Photo: Ferguson Structural Engineering Laboratory staff.

What do I mean by this? I mean more refined design techniques, better design procedures, reduction of empiricism in our design expressions, and design provisions calibrated with more representative data are bound to help us improve the state of the practice. Does that sound like a tall order? If it does, so be it. With that said, how are we to improve the state of the art without challenging the status quo?

Challenging the status quo in 2017 requires more effort than it did in the 1960s. This statement should not be taken as a criticism of the development efforts that took place

after the Second World War. In contrast, we should be giving the highest praise to the forefathers of structural engineering and those engineers and researchers who contributed to the development of design codes during that difficult time when they had to develop structural design codes of practice with limited funding. To improve upon "what's good" requires extraordinary efforts. That is really and truly the future of structural engineering research.

So, where do we go next? As far as STM is concerned, training will be the most important aspect in the implementation of the new STM provisions of the *AASHTO LRFD Bridge Design Specifications*. The good news is that such developments are underway. In this way, we can build the best bridges of the twenty-first century within our country and beyond. That is what we should all *ASPIRE*TM to do. Stay well, until the next article. 

Dr. Oguzhan Bayrak is a professor at the University of Texas at Austin.

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Building High-Quality Bridges Safer, Faster, and with Less Hassle

by Finn Hubbard, Fish & Associates Inc., and Adan Carrillo-Espinosa, American Association of State Highway and Transportation Officials

The Second Strategic Highway Research Program 2 (SHRP2) is a partnership between the Federal Highway Administration (FHWA), the Transportation Research Board (TRB), and the American Association of State Highway and Transportation Officials (AASHTO). Under this program, SHRP2 managers facilitate the delivery of financial and technical assistance to state departments of transportation and other qualifying transportation agencies. Participants can access innovative strategies and technologies to construct and manage transportation infrastructure projects more efficiently. These products, based on extensive research, are related to improving traffic safety, identifying and preventing pavement problems, relocating underground utilities, and speeding up the delivery of transportation projects.

One of these products, *Innovative Bridge Designs for Rapid Renewal*, commonly referred to as the ABC Toolkit, includes standards for accelerated bridge construction (ABC) techniques and prefabricated components. This toolkit allows construction teams to build bridges faster and within safer work zones, away from vehicle traffic. This also helps to significantly reduce the travel delays motorists experience during conventional bridge construction projects.

While a previous FHWA article in the Winter 2015 issue of *ASPIRE*[™] highlighted the ABC Toolkit and several other SHRP2 products, this current article summarizes and provides lessons learned from several bridge replacement projects funded and coordinated by SHRP2 over the past three years.

IR7 Gila River Bridge—Sacaton, Ariz.

The Gila River Indian Community (GRIC) Department of Transportation (DOT) replaced an aging four-span



Two span bridge slid into place in Arizona using steel on steel with grease for the slide system. All Photos: Finn Hubbard.

bridge with a two-span, prestressed concrete girder bridge over the Gila River near Sacaton, Ariz., about 40 miles southwest of Phoenix (see Winter 2016 issue of *ASPIRE*). The project used ABC techniques to shorten road closures from an anticipated 4-month period to 11 days. The construction manager/general contractor (CM/GC) bidding method allowed the GRIC DOT, the design consultant, and the general contractor to establish a partnership early in the planning and design phases of the project.

New substructure elements were cast-in-place under the existing bridge in preparations to slide into place the new deck and girder superstructure. The new bridge was constructed on the new substructure and partially on temporary support assemblies. This process allowed crews to install one abutment ahead of time, within a two-day weekend closure. Once all parts of the bridge were ready, the road was closed, the new bridge span was slid into place, approach slabs were paved, and the road reopened in 9 days. GRIC DOT officials will continue to consider using ABC methods in their upcoming projects. This bridge was completed in the winter of 2015 with a total construction cost of \$2,700,000.

Kittery Overpass Bridge, Route 1—Kittery, Maine

The Maine Department of Transportation (MaineDOT) replaced a concrete rigid frame bridge with a precast concrete beam structure. Route 1 Bridge in Kittery, Maine, located about 60 miles north of Boston, is a backup to Interstate 95 and therefore couldn't be restricted for a long duration. The area is also a tourist destination and local business owners



Simple span NEXT beam in Kittery, Maine.

didn't want to inconvenience customers. A cost-plus-time bidding format, also known as A+B, encouraged the contractor to limit road closures to 29 days instead of the 35 that had been anticipated originally.

Crews used Northeast Extreme Tee (NEXT) beams to take advantage of their low profile and improve the vertical clearance. As a research trial, carbon fiber-reinforced polymer prestressing strands were used in the NEXT beams to avoid corrosion and extend the service life of the bridge. Using ABC methods, MaineDOT officials met crucial shutdown and service-life requirements. This bridge was completed in the summer of 2014 with a total construction cost of \$2,560,000.

Bridge A-0087—Columbia, Mo.

The Missouri Department of Transportation (MoDOT) replaced a bridge on Route B over Loop 70 in Columbia. Since the bridge is used by University of Missouri students, replacement was scheduled during the summer months. MoDOT officials provided the contractor two options to build the single-span bridge. The first option used steel girders with a precast concrete deck placed in two modular pieces; the second option used precast, prestressed concrete box beams with a concrete overlay. Both options could be built on geo-synthetic reinforced soil (GRS) abutments without piling. The contractor chose the second option.



Simple span prestressed box sitting on geo-synthetic reinforced soil abutments in Missouri.

During the preconstruction phase it was discovered that the dry-cast modular blocks with tight freezing and thawing requirements for facing the GRS abutments could not be supplied in time. Therefore, officials opted for the use of wet-cast jumbo blocks as an alternative. Crews completed the project with a total construction cost of \$395,000 during the summer months and it opened as students returned in the fall of 2014.

Five Bridges on Interstate 39/90 Corridor—near Madison, Wis.

The Wisconsin Department of Transportation replaced five bridges using precast concrete piers. The first bridge project was on Interstate 39/90 south of Madison over a local road. With the construction of this bridge precast concrete pier columns and cap were connected using grouted splice sleeves to minimize the amount of reinforcement projecting from the precast concrete elements. Careful surveying and attention to element alignment was critical. The columns were placed on the cast-in-place footings and all elements came together and fit as planned.



Precast concrete pier cap being placed on precast columns in Wisconsin.

This precast approach saved approximately 3 weeks of construction time per bridge, but the real advantage was in the safety aspects of this process. Construction crews were able to work in the median of the interstate and complete their activities faster than using conventional cast-in-place construction. This reduced the crews' exposure to traffic and travel delays. In this instance, safety became the driving force to using ABC techniques, resulting in a shorter schedule. These five bridges were completed in the summer of 2016 with a total construction cost of \$6,897,000.

Seney National Wildlife Refuge, J to H Bridge Replacement—near Seney, Mich.

The FHWA funded the replacement of a single-lane timber bridge in the Seney Wildlife Refuge near Seney, Mich. ABC techniques were used on this project to reduce



Three span prestressed box bridge built during the winter of 2015 in Upper Michigan.

disturbances to surrounding wetlands. A fully precast concrete option was chosen using precast concrete substructure units with precast, prestressed concrete box beams and precast, prestressed concrete piles to support the structure.

Building a bridge in the middle of the winter in the upper peninsula of Michigan was no small challenge. But the use of precast concrete allowed for the construction of this bridge in such a cold environment and the old bridge was removed while the wetlands were frozen. The placement of the concrete for the precast concrete connections and the overlays was conducted in a heated enclosure. This bridge was completed in the winter of 2015 with minimal impact to the surrounding habitat and a total construction cost of \$1,180,000.

SHRP2 Training Opportunities

FHWA and AASHTO are hosting a series of one-day training sessions for those interested in learning about the ABC Toolkit and to encourage the construction of more bridges using the toolkit. **A**

Finn Hubbard is senior vice president with Fish & Associates Inc. in Middleton, Wis., and Adan Carrillo-Espinosa is a marketing and communications specialist with the American Association of State Highway and Transportation Officials in Washington, D.C.

EDITOR'S NOTE

Transportation officials interested in hosting a training session should contact AASHTO SHRP2 Implementation Manager Pam Hutton at phutton@aaashto.org for details. For additional information on ABC or other SHRP2 strategies please visit: www.fhwa.dot.gov/shrp2.

Federal Highway Administration Releases Mobile Application for Bridge Inspector's Manual



by Doug Blades, Federal Highway Administration

When certified inspectors perform bridge inspections, they rely on a 2000-page manual to guide them. The *Bridge Inspector's Reference Manual* (BIRM) is typically contained in two three-ring binders and contains just about everything a bridge inspector needs to know about the national bridge inspection standards, the duties of a bridge inspection team, basic bridge terminology, and how to perform bridge inspections. But because of its bulkiness, bridge inspectors hesitate to carry the manual into the field, preferring instead to leave the two binders in their office or vehicle. But what if bridge inspectors could fit the entire BIRM into their pocket?

That's what the Federal Highway Administration's (FHWA) National Highway Institute (NHI) has done. To make the BIRM more accessible and easier to use, NHI has developed a free mobile application of the BIRM that bridge inspectors can access on their smartphones or tablets.

"NHI strives to develop reference material in a format that can be useful to practitioners," says Louisa Ward, the BIRM application project manager and training program manager at NHI. "Today's professionals demand just-in-time learning and the BIRM app fills that need for the bridge inspection community."

The BIRM application includes all the content from the manual, including information on improved bridge inspection techniques, culverts, fracture critical members, cable-



A bridge inspector uses the Bridge Inspector's Reference Manual Application on his tablet. All Photos: Federal Highway Administration.

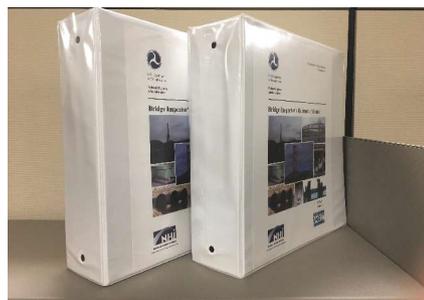
stayed bridges, prestressed concrete segmental bridges, moveable bridge inspection, underwater inspection, nondestructive evaluation, and critical findings.

With the importance of our inspection program growing as our bridges age, there is greater need than ever to have inspections that are both high quality and consistent among inspection teams. By optimizing the *Bridge Inspector's Reference Manual* for mobile devices, inspection teams can routinely use the manual to ensure we have the best inspections possible.

The BIRM application has many features to make the bridge inspector's job easier:

- The application works on the Apple iOS and Android platforms. NHI plans to expand the BIRM app to work on the Microsoft Windows and Blackberry platforms.

- The application optimizes the screen size so that information is displayed full size on smartphones and tablets.
- Organized into chapters and topics so that users can download either the entire



Bridge Inspector's Reference Manual (2 Volumes).



Bridge Inspector's Reference Manual Application Icon available for download on the iPhone and Android platforms.



A bridge being subjected to a safety inspection.

Now with the application and an iPad, I have the entire manual at my fingertips while standing at a bridge.

can be used in remote locations where internet connections are either limited or unavailable.

- Inspector-generated notes can be shared with team members and team leaders.
- “The world of bridge inspection will never be the same thanks to the BIRM application,” says Patrick C. Park II, QA/QC bridge inspection team leader for the West Virginia Department of Transportation. “It’s so convenient and easy to use when compared to the old bulky hard-copy binders and laptop versions. Now with the application and an iPad, I have the entire manual at my fingertips while standing at a bridge. With this application, the BIRM now becomes a powerful field reference.”

For more information about the BIRM application, please visit www.fhwa.dot.gov/bridge/birm/. 

- manual or only the content they desire.
- Capable of performing both keyword and full-text searches and contains a searchable glossary. Pop-up pictures and figures allow users to click on any image and enlarge it to fit the appropriate screen.
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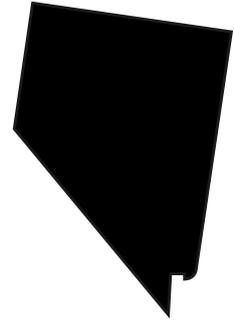
Benicia Martinez Bridge in California

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Nevada

by Jessen Mortensen, Nevada Department of Transportation



As the Nevada Department of Transportation (NDOT) approaches its 100-year anniversary, there is a continuing effort to explore more economical and innovative methods of maintaining and expanding the state's infrastructure while keeping the traveling public safe and connected.

Nevada is fortunate to have the lowest percentage of deficient bridges in the nation, as ranked by the American Road and Transportation Builders Association. However, like other states, many of Nevada's bridges were constructed as part of the interstate system and are quickly approaching the end of their original service lives. While the state has managed to reduce the number of deficient bridges in recent years, it will become more difficult to maintain this trend as approximately 38% of the state-owned bridges currently exceed 50 years of age.

Concrete Bridges in Nevada

Concrete bridges have always played a major role in Nevada's infrastructure and while it continues to utilize precast concrete and steel girders, cast-in-place (CIP), post-tensioned concrete box-girders are the most commonly constructed bridge type throughout the state, and have been since their first use in the early 1970s.

Widespread use of CIP post-tensioned concrete box-girder bridges may seem foreign in other parts of the country where precast concrete beams are a more economical option. However, a problem somewhat unique to Nevada is the lack of girder fabricators in the state. Historically, all steel and precast concrete beams have been supplied by out-of-state contractors in Utah, Arizona, or California. Shipping often contributes to the additional cost associated with these superstructure types. Cost analysis of many of our bridges has shown CIP concrete box girders to be the most economical, followed by precast concrete and steel.

In the past, precast concrete girders had limited use throughout the state. Records indicate the occasional construction of precast concrete box-beam and girder bridges dating back to the 1930s, with the highest concentration in the 1960s. Only in the last 30



US 50 Cave Rock Tunnel extension for rockfall protection. Photo: Nevada Department of Transportation.

years has there been a resurgence in the use of precast concrete structures, primarily in design-build jobs. Several factors have contributed to this increase.

There has been a resurgence in the use of precast concrete structures.

The larger design-build projects have included improvements to major arterials in urban areas where falsework is not feasible. In these locations, steel girders were the previously preferred alternative because of the price associated with precast concrete girders. However, with standardized shapes leading to quicker designs, increased speed of construction, and more competition amongst suppliers, precast concrete girder prices have become more competitive, and in some instances, more economical than steel girders in Nevada.

Segmental construction has been utilized only once in Nevada while building the Las Vegas

Spaghetti Bowl, a project that included several large flyover structures. Very few other projects in the state have had the size or number of structures to prove economical for this type of construction.

Although there has been more diversity in the recent construction of bridges in the state, CIP post-tensioned concrete box girders continue to be widely used because of the many benefits they offer. The bridges have proven to be low-maintenance, durable structures that exhibit excellent seismic performance. They are an economical option that local contractors are familiar with and know how to build, and the majority of the work is performed by local laborers, supporting the state's economy.

Current Trends

There is currently a substantial increase in the pace of construction of bridges in the state, primarily attributed to three large projects underway in the Las Vegas valley. Over the next few years, Project NEON and the two phases of the Boulder City Bypass will add nearly 50 bridges to the state's structural inventory of approximately 2000 bridges. More than 40 of these structures are precast or CIP concrete. While this may not seem significant to many



Interstate 80 Silver Zone Summit wildlife crossing. Photo: Nevada Department of Transportation.

of the states with larger construction programs, NDOT typically constructs fewer than a dozen bridges statewide per year.

Project NEON is the largest public works project in Nevada history, and includes operational improvements to the I-15 Las Vegas corridor from Sahara Avenue to the Spaghetti Bowl. Existing infrastructure and maintenance of traffic along this highly traveled section of road added complications to the proposed construction of 30 new bridges. The project reference design documents included a mix of CIP concrete, precast concrete, and steel structures to account for the geometric constraints at various locations. The design-build contractor chose to build all structures utilizing precast concrete girders and partial-depth precast concrete deck panels. All precast concrete elements will be manufactured in Phoenix, Ariz., and transported to the jobsite.

NDOT and the Regional Transportation Commission of Southern Nevada are simultaneously constructing both phases of the Boulder City Bypass. Nearly 15 miles of new highway are being built as part of Interstate 11 extending from Henderson to US 95 (Phase 1) and continuing to US 93 near the Hoover Dam Bypass Bridge (Phase 2). The roadway corridor includes mixed terrain as it travels through the valley and continues past an extremely rugged mountainous section. A variety of structures are

being built including CIP post-tension concrete box girders, precast concrete arches, steel girders, and conventionally reinforced concrete bridges to accommodate the safe passage of both the traveling public and wildlife in the area.

Highlighted Projects

The following projects highlight more unique structural applications that have been used recently throughout the state. While not all were large in scale, each had concrete elements that contributed to a more economical and innovative design.

Each had concrete elements that contributed to a more economical and innovative design.

This fall, NDOT completed the extension of the US 50 Cave Rock tunnel in the Lake Tahoe basin. The original tunnel, constructed in 1931, was a CIP concrete liner built through a large rock outcropping at the lake's edge. In response to frequent rock falls in the area,

NDOT installed temporary netting on the slopes above the structure and chose to lengthen the tunnel to provide additional protection for the traveling public. A context sensitive design was developed to satisfy stakeholder concerns that included architectural treatments to minimize the environmental and cultural impacts of the construction and a simplified design to reduce construction duration. Sculpted shotcrete was applied to the exterior surfaces to blend the tunnel with the surrounding landscape and a deep layer of sand was placed on top of the structure to reduce the impact of large rocks.

In an effort to further reduce the construction window, the contractor proposed the substitution of precast concrete beams for the CIP rectangular sections detailed in the plans. NDOT worked closely with the contractor to successfully modify the design and complete construction ahead of schedule.

In recent years, NDOT has utilized precast concrete arches in a variety of applications. Because of cost, aesthetics, and speed of design and construction, arches have become an appealing option for water crossings, animal safety crossings, and grade separations.

NDOT has used precast concrete arches on several wildlife overcrossings with great success. Camera monitoring of the structures has confirmed frequent use on several critical migratory routes in the northeast corner of the state. The structures blend well with the environment and are ideal for the placement of topsoil and landscaping to provide the comfort level necessary to encourage animals to cross, thereby helping to reduce potential vehicle-animal collisions. The Silver Zone Summit crossing near Wendover is regarded as one of the largest crossings in the country and spans both directions of Interstate 80.

The newly constructed Interstate 15 Mesquite interchange is another notable example of the use of precast concrete arches. The city of Mesquite, Nev., and NDOT worked together



Interstate 15 Mesquite interchange constructed using precast concrete arches. Photo: Horrocks Engineers.



Flyover constructed using post-tensioned, cast-in-place concrete box girders as part of the Centennial Bowl in Las Vegas, Nev. Photo: Nevada Department of Transportation.

to develop and administer the design-build contract to construct the new interchange. Original concepts included a steel structure that sloped significantly to match the grade and extensive mechanically stabilized earth walls along the alignment. The contractor proposed

an alternative technical concept that included the use of precast concrete arches. The resulting structure was an economical option that blended well with the surrounding topography and provided an attractive entrance to the city.

The versatility of post-tensioned, cast-in-

place concrete bridges is displayed with the construction of the Centennial Bowl flyover in Las Vegas. The 11-span structure is nearly 1/2-mile long with maximum spans of 250 ft. At its greatest height, it stands 70 ft tall and curves along an 847-ft radius. Four superstructure types were evaluated during design, including steel plate girder, precast concrete I-girder, and precast concrete U-girder. A number of factors were considered in determining the appropriate superstructure type including cost, aesthetics, geometry, constructability and long-term maintenance. The CIP, post-tensioned concrete box-girder was ultimately chosen for its suitability to the site. Future phases of the Centennial Bowl include two other structures of similar size and type.

NDOT will continue to be challenged in the future with maintaining the health of our structural inventory. In an effort to further extend budgets, economical construction methods must be utilized, and concrete structures will likely remain the mainstay of the NDOT bridge program. 

Jessen Mortensen is the state bridge engineer for the Nevada Department of Transportation in Carson City, Nev.



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Halvard W. Birkeland
Wisdom of the Structure

by Greg Banks, BergerABAM Inc.

Our aging highway infrastructure has allowed us to witness concrete damage due to corrosion of reinforcement steel, which has led to significant costs in maintenance and repair. As Halvard Birkeland had stated, it is now our duty as engineers to develop strategies and mitigate costs associated with preservation of existing infrastructure. Rising to the challenge, significant efforts have been deployed to develop more durable design strategies. One such effort, developed through the Strategic Highway Research Program 2 (SHRP2), is a service life design approach.

The service life design approach provides a systematic way to assess the service performance of a given structure with the goal to find new and better ways to design structures that will last longer and require less maintenance. The approach considers a wide range of factors such as project location, environmental conditions, materials, and anticipated load demands with the primary objective being to avoid development of degradation mechanisms.

For concrete structures, degradation first occurs when substances from the surrounding environment penetrate into the concrete via cracks and either accumulate over time within the outer concrete layers or penetrate inward toward the reinforcement. Carbonation, chloride penetration, and sulfate accumulation accelerated by cyclic wetting and drying are examples of such means of penetration. After time, the protective layers break down and/or critical levels of detrimental substances are reached and corrosion commences.

The focus of this article is not to go through the service design approach (readers are directed to the references for details), however, to introduce an innovative partially prestressed concrete concept that could be used to enhance the durability of our transportation infrastructure. The concept being introduced stems from research conducted by the U.S. Navy, which invested in

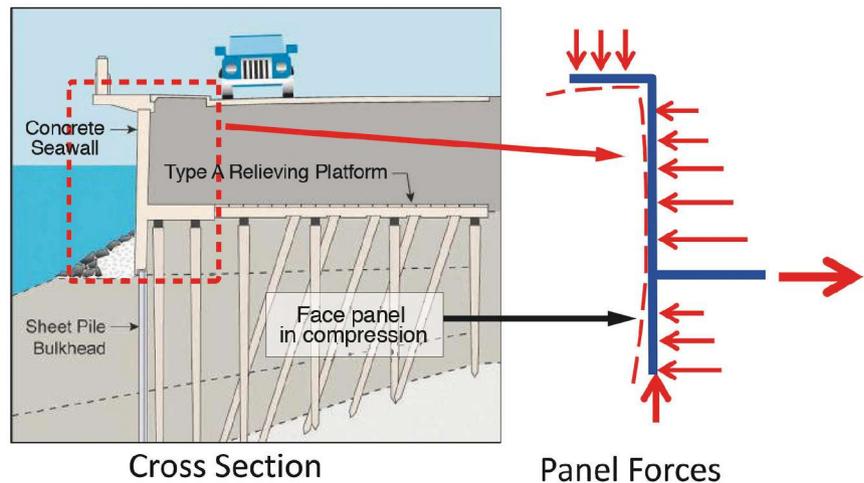


Figure 1. Pacific Northwest pier construction using gravity-induced prestressed concrete with free body diagram showing compression forces on panel face. All Figures: BergerABAM Inc.

a multi-year project with the goal to develop a fully prestressed concrete pier system that minimizes concrete cracking to produce more durable pier structures.

U.S. Navy Partially Prestressed Concrete Pier Concept

Historically, pier structures in the Pacific Northwest have consisted of reinforced concrete flat slab decks supported by precast, prestressed concrete piles. Due to the significant investment being devoted to maintenance and repair of these structures, the U.S. Navy invested in a multi-year research program with the goal of developing a prototype for fully prestressed concrete pier and sea wall designs with similar features to their existing reinforced concrete pier designs, that would minimize cracking to produce a more durable coastal structure.

Gravity-induced prestressed concrete.

Due to constructability issues related to the use of post-tensioning in some areas, the age of precast concrete element integration, curing conditions, or other concerns, a fully prestressed (pretensioned with post-tensioned) system using gravity-induced prestressed concrete was developed (Figure 1). This system was developed with the following objectives:

- Reducing the routine dependency on post-tensioning
- Using precast precompressed concrete elements for all structural members exposed to saltwater, thus reducing cracking on the exposed faces
- Improving performance of precast, prestressed concrete elements while simplifying fabrication and installation
- Increasing the modularity of elements to provide the designer with flexibility to configure the pier to meet structural and functional requirements
- Reducing cost to make the new pier concept comparable to current Navy pier designs

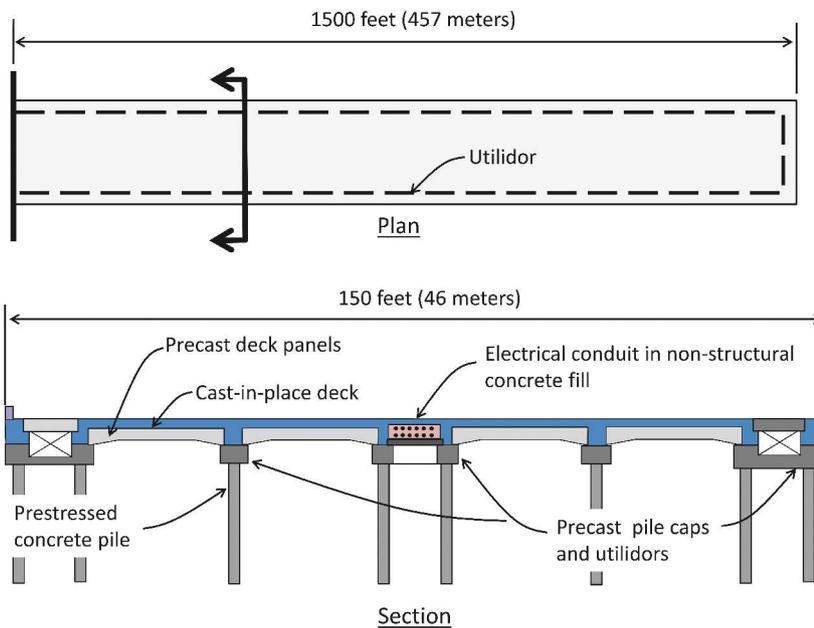


Figure 2. Schematic plan and section of the sample pier.

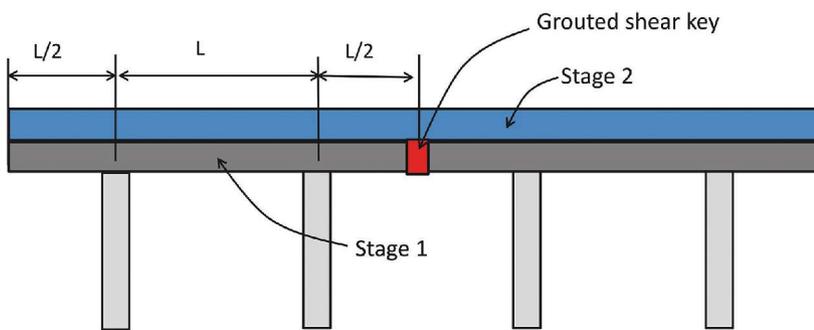


Figure 3. Cantilevered cap beams.

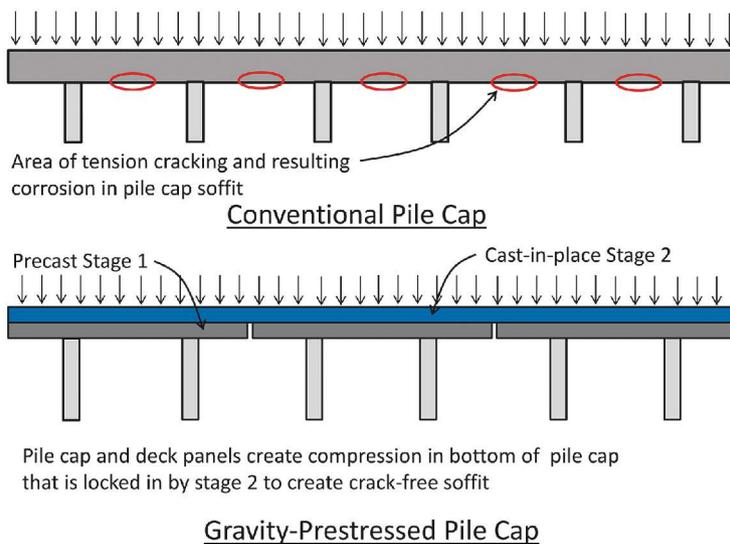


Figure 4. Conventional versus gravity-induced prestressed pile caps.

The partially precast concrete pier system, shown in Figure 2, consists of precast prestressed concrete piles, precast concrete pile caps, and precast concrete deck panels. The elements are integrated with a cast-in-place reinforced concrete topping slab. The precast concrete pile caps, shown in Figures 3 and 4, replace conventional cast-in-place concrete pile caps. The precast concrete pile caps are continuous over two piles with cantilevered segments on each end that extend to midspan of the adjacent bay.

Using the concept of gravity-induced prestressing, the adjacent stage 1 precast concrete pile cap beam elements are not connected before the placement of the deck panels and the stage 2 closure concrete. The dead loads are thus carried by the cap beam segments and live loads are carried on the continuous structure. In this configuration, the bottom of the pile cap will be under compression or low levels of tension under dead and live loads, which will minimize cracking. The stage 2 closure concrete was cast-in-place and contained polypropylene fibers to minimize early age cracking.

Applicability to Infrastructure

There are many similarities between waterfront pier structures and bridge transportation structures. Concepts applied to one could most likely be applied (at least in concept) to the other. In the current case, bridge structures often contain cast-in-place dropped crossbeams used to support longitudinal precast, prestressed concrete girders spanning between piers. The precast, prestressed concrete pile cap concept developed in the noted U.S. Navy research project could easily be adopted to multi-column bridge structures (Figure 5).

The conventional stage 1 cast-in-place concrete crossbeam would be replaced with a stage 1 precast crossbeam(s) spanning continuously over two columns with cantilever segments extending to midspan of the adjacent column bay. The precast, prestressed concrete girders would then be set and the superstructure diaphragms and bridge deck cast before casting the stage 2 pier diaphragm (assuming a stage 2 pier diaphragm pour exists).

Also illustrated in Figure 5, it would not be hard to imagine applying a similar concept to full-depth precast concrete deck panels spanning transversely between longitudinal precast, prestressed concrete girders. With bridge decks, thought would need to be given to longitudinal tensile forces developing across the transverse panel joints and making

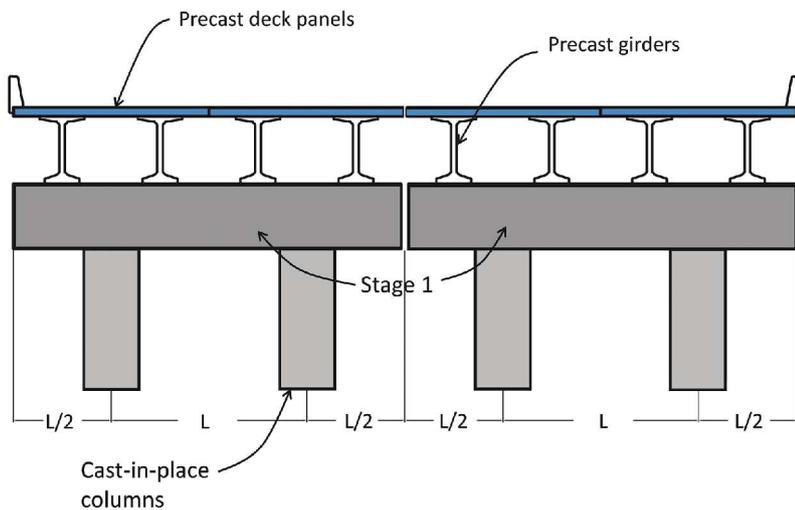


Figure 5. Cross section of a typical multicolumn bridge.

sure residual compression exists across the joint under the design service conditions.

Closing Remarks

Although the concept of gravity-induced prestressing (or compression on exposed faces) presented is not inclusive to all

structural elements, it is another tool in the toolbox, and another step towards improving the durability of concrete structures. Engineers working with the Navy using prestressed (both pretensioned and post-tensioned) concrete elements have seen reduced cracking. Therefore these structures

have the potential to be highly durable structures exposed to brutal environments by forcing corrosion causing environmental substances such as chlorides to travel through concrete versus annulus spaces created by cracks.

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Greg Banks is a bridge project manager and construction liaison engineer in the Federal Way, Wash., office of BergerABAM Inc.

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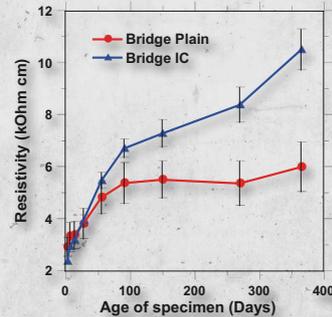


Figure 28: resistivity measurement with a Wenner array.

Lightweight Aggregate Improves Service Life for Concrete Bridges

The topic of extending the service life of concrete structures, which was discussed in the Perspective article by Mertz and Wasserman in this issue, has become a major concern in the design of major bridges. It is also being considered more frequently for conventional structures.

While a comprehensive and reliable approach to ensuring a certain service life in a bridge may not yet be available, structural lightweight concrete and concrete that has been internal cured using prewetted lightweight fine aggregate meeting ASTM C1761 Standards, have both been shown in laboratory and field applications to be dependable strategies to improve the long-term performance of concrete. The improvement in performance is attributed to both reduced permeability and reduced cracking, the two

main contributors to deterioration in concrete structures. Concrete incorporating lightweight aggregate has also been shown to have beneficial properties related to durability and long-term performance, such as a potential for mitigation of ASR and improved resistance to fires.

Information on these topics, including studies and papers that demonstrate the improved properties of concrete with structural lightweight aggregate, can be obtained on the ESCSI website or by contacting ESCSI.



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The AASHTO LRFD Bridge Design Specifications: Section 5 Reorganization

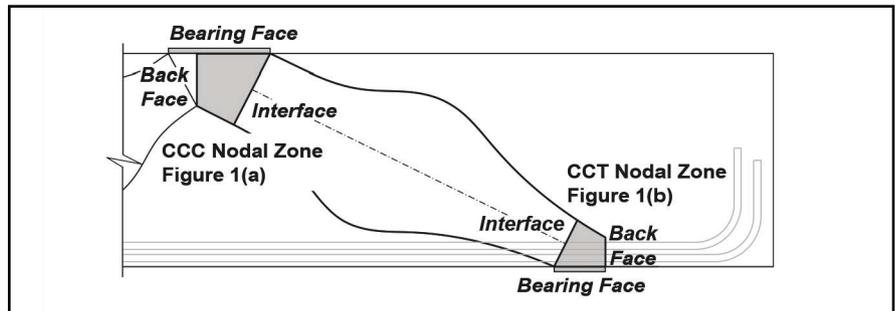
by R. Kent Montgomery, FIGG, Dr. Shri Bhide, Bentley Systems Inc., and Gregg Freeby, Texas Department of Transportation

The first edition of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* was published in 1994. Since that time, the AASHTO LRFD specifications have been continuously updated with interim revisions. After nearly 25 years some users were expressing some frustrations about the concrete design section of the specifications, Section 5. Many engineers felt the organization of the section had become confusing and that there were inconsistencies among articles. Therefore, there was a need to reorganize Section 5 of the AASHTO LRFD specifications to provide better organization, clarity, and consistency among articles.

Reorganization Process

A pooled fund project to reorganize Section 5 was initiated by the AASHTO T-10, Concrete Design Technical Committee of the Subcommittee on Bridges and Structures (SCOBS). Oversight throughout the project was provided by the AASHTO T-10 committee and the Federal Highway Administration (FHWA). To obtain a broader perspective, the AASHTO T-10 committee invited industry liaisons, including the Precast/Prestressed Concrete Institute (PCI) and the American Segmental Bridge Institute (ASBI), to participate in the reorganization. Modjeski and Masters, along with Dr. Dennis Mertz, was selected as the contractor for the reorganization process, with Dr. John Kulicki and Dr. Dennis Mertz taking the lead roles in editing and tracking changes.

The project began with a survey of stakeholders early in 2013. The results of this survey were remarkably consistent as to what improvements to Section 5 were needed and provided clear direction to the augmented reorganization committee. Past interim revisions were critically reviewed for accuracy, as well as to make sure no inconsistencies with other articles had been introduced into Section 5. At this point a revised table of contents (TOC) was developed by the reorganization committee. This TOC set the major reorganization of the section. A working draft of the reorganized articles was then developed as the starting point for determining what further changes, clarifications, and updates were needed.



New and enhanced figures explaining strut-and-tie model.

It was determined that the reorganization should be an evolution of Section 5 to make it easier to understand and utilize. It was not to be a revolution of new concepts and procedures, unless especially needed. Major decisions included:

- Keeping the units of kips and inches
- Advancing the concept of beam and disturbed design regions (B-Regions and D-Regions) and promoting the use of the strut-and-tie model (STM) for the analysis of disturbed regions
- Keeping the current bending and axial design articles for B-Regions
- Reducing the number of shear design procedures
- Consolidating prestressed reinforcement details, non-prestressed reinforcement details, and seismic details into three separate articles
- Having topics and procedures appear only once in the section
- Organizing Section 5 such that more common design provisions appear before more unique design provisions

During the project, the reorganization committee determined that two major changes were especially needed. These changes were a significant reformulation of the STM provisions and the addition of an article on anchors. The reformulation of the STM provisions was deemed of such importance that the changes were developed ahead of the reorganization and were included in the 2016 Interim Revisions.

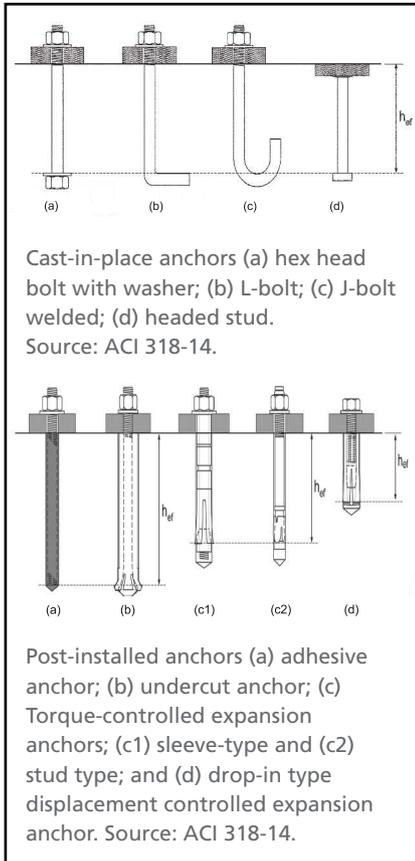
During the course of the reorganization, there were five working meetings of the reorganization committee and seven draft documents. Over 1000 comments on the drafts

were addressed and incorporated. In late 2015, the reorganization committee had a completed draft that satisfied the original goals. This draft was made available to AASHTO members for review and comment through the typical SCOBS process. Additionally, a webinar was held to help inform the AASHTO members about the reorganized Section 5. The webinar was taped and is available for those interested in viewing this resource. A final version of Section 5 was balloted at the 2016 annual SCOBS meeting and unanimously passed. The reorganized Section 5 will be included in the Eighth Edition of the *AASHTO LRFD Bridge Design Specifications* available in 2017.

Reorganized Section 5—The Big Picture

Articles 5.1 through 5.5 are largely unchanged except for the introduction of B-Regions and D-Regions in Article 5.1 and articles defining these regions in Article 5.5. Old Article 5.6 received a lot of comments from the survey and contained somewhat miscellaneous information, including provisions for imposed deformations and the STM method. These provisions have been moved to more appropriate articles in Section 5.

Articles 5.6 and 5.7 now cover the sectional (B-Region) design provisions for flexure and axial loads, and shear and torsion, respectively. The shear design section has been condensed. This article now covers general shear and torsion requirements, such as minimum reinforcement and bar spacing, one shear design procedure (modified compression field theory [MCFT]), and shear friction provisions. The outdated prestressed concrete beam shear design



to all concrete bridge types, except pretensioned beams with compressive strengths less than 10 ksi where historic evidence has shown web cracking to not be an issue.

Articles 5.10 and 5.11 cover non-prestressed reinforcement and seismic details, respectively. Note that now prestressing details, reinforcing details, and seismic details each have their own article rather than being mixed together throughout various articles as was the case before the reorganization. Article 5.12 contains provisions for specific structure types and components, such as beams and girders, segmental construction, and footings. This article contains much of what used to be contained in old Articles 5.13 and 5.14.

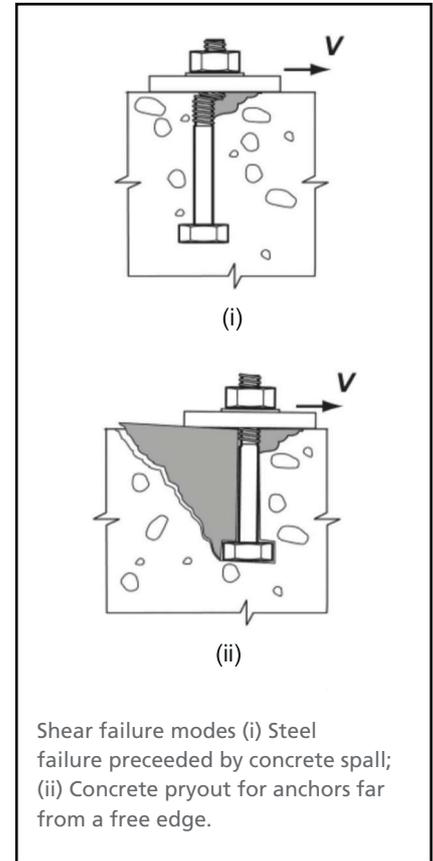
Article 5.13 is new and covers concrete anchors. These are anchor studs and headed bolts, not to be confused with post-tensioning anchorages. This article is linked to Chapter 17—Anchoring to Concrete of the *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)*, with some exceptions. Article 5.13 provides guidance on what types of anchors in ACI 318-14 are covered in Section 5. The resistance of cast-in-place anchors can be obtained by the calculation methods of ACI 318-14, or by using the acceptance testing methods specified in ACI 355.2-07, *Qualification of Post-Installed Mechanical Anchors in Concrete & Commentary*. Post-installed anchor resistance is obtained using the acceptance testing methods in ACI 355.4-11, *Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary*. For adhesive anchors, the resistance is further reduced by 50% for sustained tensile loads.

Article 5.14 covers durability. Rather than being prescriptive, it serves as a toolbox of best practices that owners and designers may choose from to achieve greater durability. Finally, Article 5.15 still contains the references.

Throughout the process of reorganizing Section 5, articles were reworded for better clarity. The somewhat ambiguous term “mild reinforcement” was replaced with the preferred “nonprestressed reinforcement” to add clarity to these provisions. Conditional statements were made consistent throughout the section and terminology was condensed and made consistent throughout. Minor corrections were made throughout for any errors that were found.

Summary

The reorganization of Section 5 was a comprehensive effort to improve the concrete design section of the AASHTO LRFD specifications. The augmented reorganization committee included the AASHTO T-10 Committee and representatives from FHWA, as well as liaisons from the concrete industry. This



provided a broad range of experience and views to help make the specification as clear, accurate, and user-friendly as possible. The authors of this article hope that users of the reorganized Section 5 concrete specification will find that this goal has been achieved and that this helps make the design of concrete bridges more efficient, both from the standpoint of design efficiency and the engineering effort to produce the design.

Additional Resources

To aid with the transition, a “cross-walk” is available that lists the old article numbers for all the new article numbers and vice versa. A cross reference document is also available for cross-referencing other AASHTO specifications, such as other sections of the AASHTO LRFD specifications, the *AASHTO LRFD Bridge Construction Specification*, and the *Manual for Bridge Evaluation*. This will aid engineers as they implement designs with the new Section 5, as well as owners and software developers as they update design manuals and software. The aforementioned webinar is also available. 

EDITOR'S NOTE

Go to www.aspirebridge.org/additionalresources for more information.



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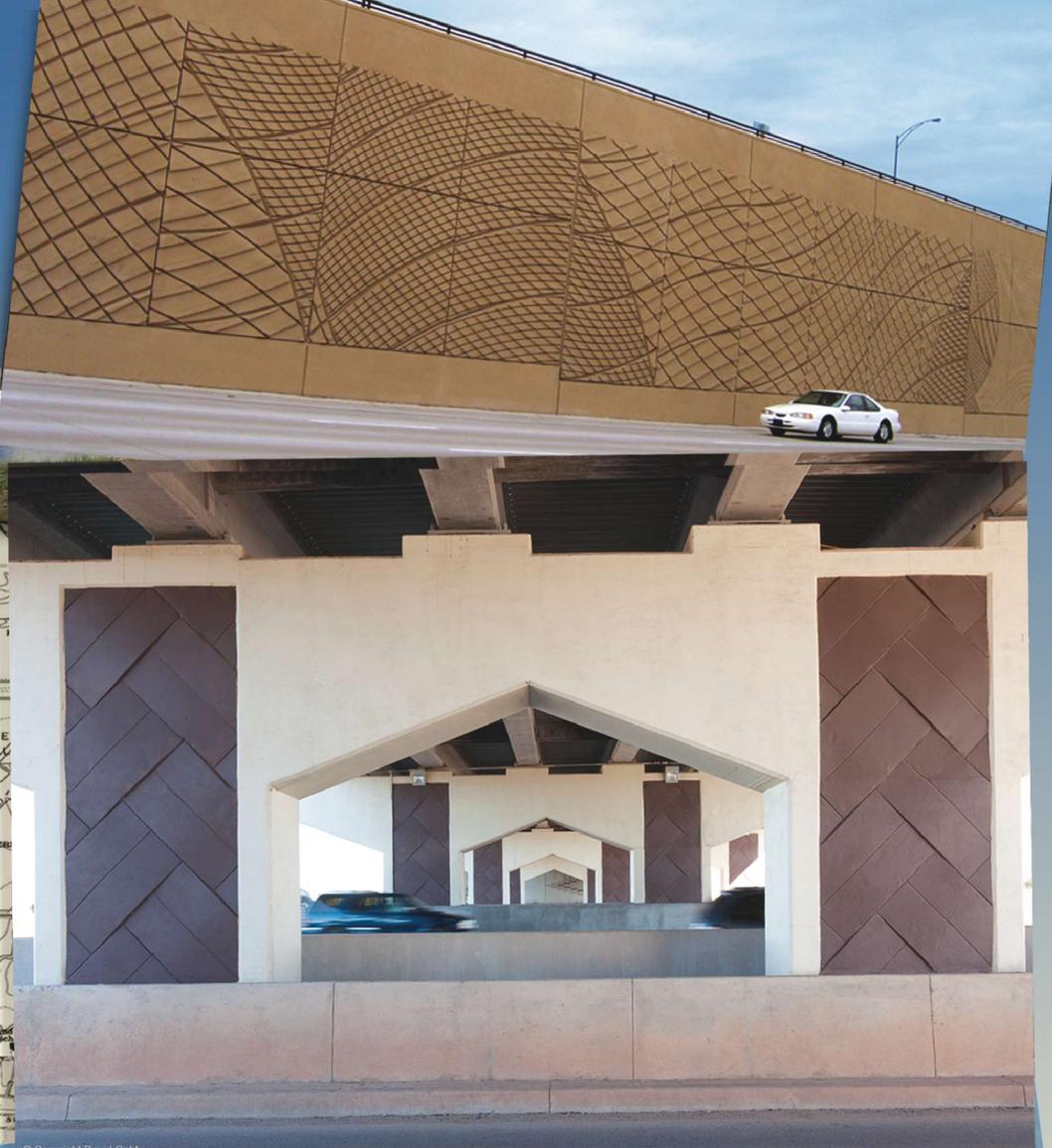
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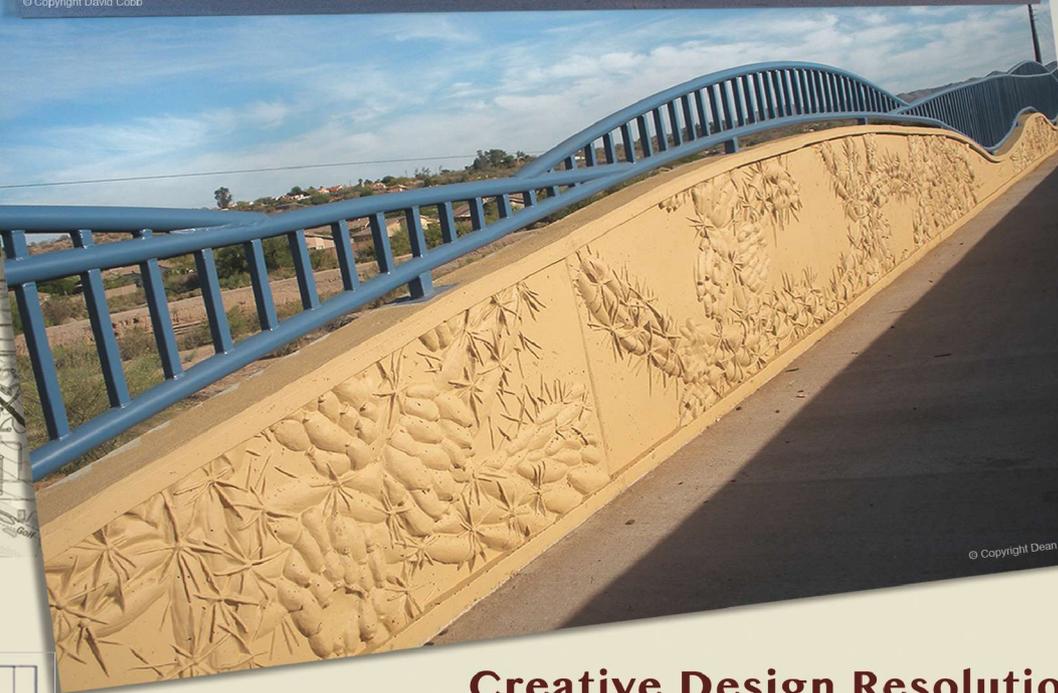
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