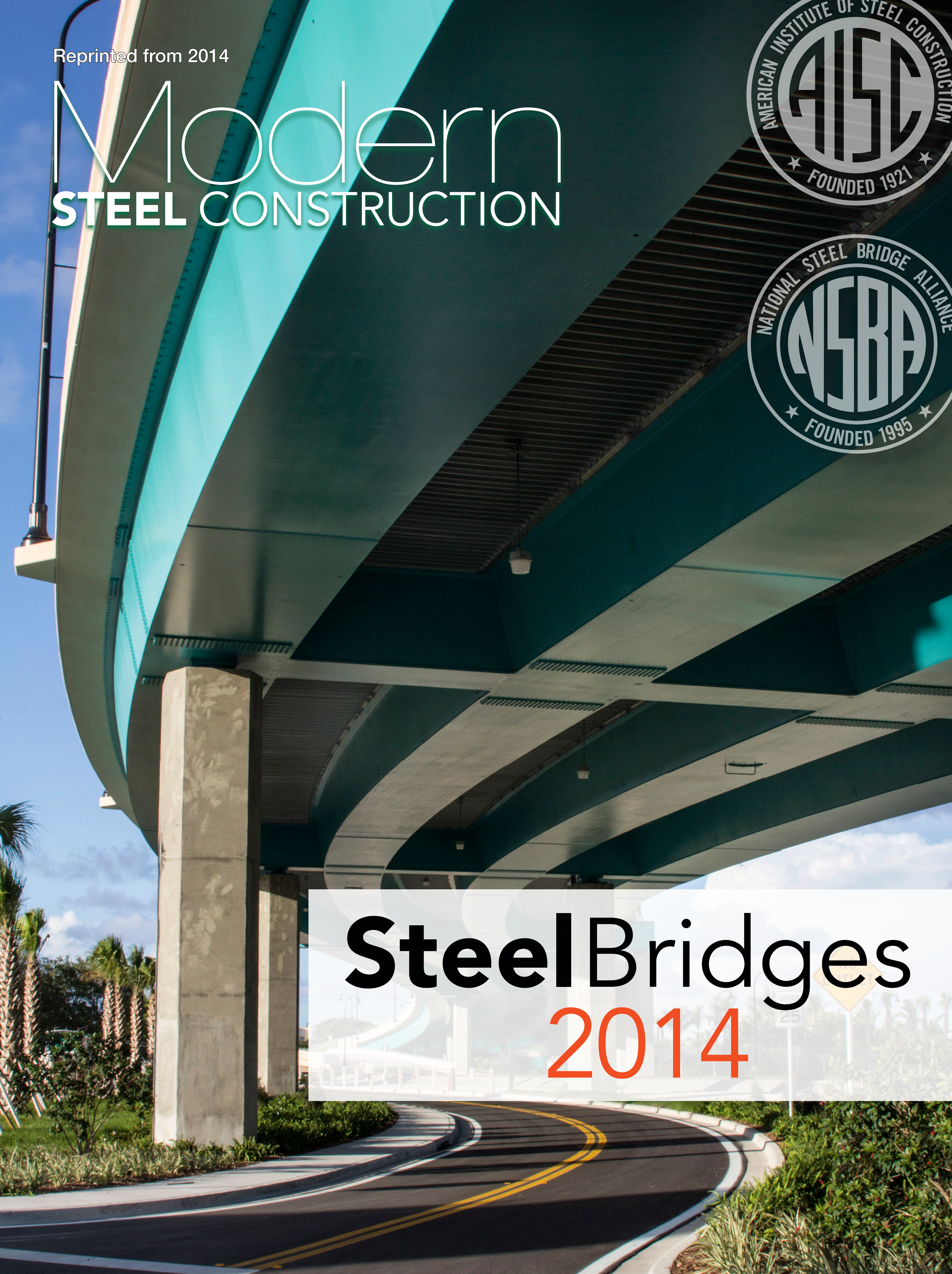
Reprinted from 2014

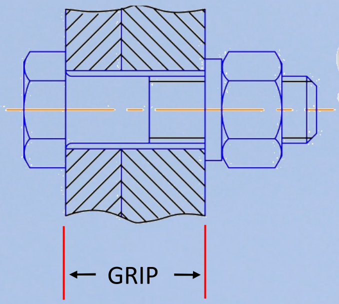
Modern STEEL CONSTRUCTION



SteelBridges 2014

Technical Spotlight

Bolt Length Selection



Nominal Bolt Diameter	To determine required bolt length add to grip (inches)		
	No washers	1 washer	2 washers
1/2	11/16	55/64	1-3/64
5/8	7/8	1-1/32	1-3/16
3/4	1	1-5/32	1-5/16
7/8	1-1/8	1-9/32	1-7/16
1	1-1/4	1-13/32	1-9/16
1-1/8	1-1/2	1-21/32	1-13/16
1-1/4	1-5/8	1-25/32	1-15/16
1-3/8	1-3/4	1-29/32	2-1/16
1-1/2	1-7/8	2-1/32	2-3/16

*To get bolt length required if beveled washers are used, add to grip length the amount in "no washer" column plus 5/16 inch for each beveled washer

*Bolt lengths are commonly available in 1/4 inch increments up to 6 inches, over 6 inches it is more common for 1/2 inch increments. SLSB commonly provides 1/4 inch increments in long lengths when requested.

STRUCTURAL BOLTS

ANCHOR BOLTS

WELD STUDS

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sales@stlouisscrewbolt.com
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Welcome to Steel Bridges 2014!

This publication collects all the bridge related articles that were published in Modern Steel Construction in 2014. Topics ranged from informative and academic to fun and enlightening. As always, we are proud of the amount and variety of information we provided.

These articles would not have been possible without the efforts of the authors, most of whom volunteered their time. Their willingness to share their experience and expertise benefits the entire bridge community. As we look forward to 2015, if you are aware of a project or topic that should be featured, don't hesitate to contact us. There are great stories out there and we want to share them.

It's hard to believe 2014 is already behind us but I hope you share in my enthusiasm for all 2015 holds. We look forward to working with you in the coming year.

Bill McEleney
NSBA Managing Director

The National Steel Bridge Alliance is dedicated to advancing state-of-the-art steel bridge design and construction. The NSBA stands united with industry businesses and agencies interested in the development, promotion, and construction of cost-effective steel bridges.

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HANGING ^ 10 (over the)

BY PAUL CHUNG, P.E., AND JASON FANG, P.E., PH.D.

The widening of Interstate 10 in suburban Los Angeles provided the opportunity to build a new pedestrian overcrossing with an attractive through-truss as the centerpiece.

HIGHWAY WIDENING is nothing new in southern California. The recent addition of high-occupancy vehicle (HOV) lanes to a roughly 12-mile stretch of Interstate 10 east of Los Angeles illustrates this. Of course, as a highway expands, surrounding infrastructure must also be altered. As a result of the I-10 expansion, the concrete Bess Avenue Pedestrian Overcrossing—which opened in 1956 and crosses I-10 in Baldwin Park, Calif., roughly 20 miles east of downtown Los Angeles—had to be demolished and rebuilt in order to span the newly widened freeway.

Paul Chung (paul.chung@dot.ca.gov) is the structure design quality manager for the California Department of Transportation in Los Angeles and currently manages the structure program of Caltrans Design-Build projects in Southern California. **Jason Fang** (jason.fang@dot.ca.gov) is the senior bridge engineer for the California Department of Transportation in Los Angeles.

The replacement bridge, one of several being replaced or expanded for the project, was designed to span 80 ft over the I-10 westbound lanes and 157 ft over the eastbound lanes and HOV lanes, for a total bridge length of 654 ft, including approach ramps. While these approaches employ concrete box girders, a steel through-truss serves as the main span over the freeway. The new bridge, which doubles as a structural landmark and gateway for the town, provides an expanded 10-ft wide walkway, which meets current ADA requirements, and convenient pedestrian access over the freeway to Baldwin Park's downtown.

Pedestrian and Seismic Vibration

It is now well known that, under pedestrian excitation, footbridges can exhibit large-amplitude vibrations that can impact serviceability. This is especially true for a footbridge with a relatively longer span, which can become a line-like structure with low natural frequency—e.g., close to or less than 1 hertz (Hz). If not adequately designed or mitigated, such a bridge can exhibit vibrations of significant amplitude when subjected to pedestrian loading within the designed static capacities of the bridges. The AASHTO LRFD *Specification for Pedestrian Bridge Design* requires that the fundamental frequency in a

▲ The bridge's total length is 654 ft, including approaches.

➤ A special 247.5-ft-long through-truss is used as the main bridge element.

vertical mode of the pedestrian bridge without live load shall be greater than 3.0 Hz to avoid the first harmonic. In the lateral direction, the fundamental frequency of the pedestrian bridge shall be greater than 1.3 Hz to prevent the users from the discomfort or concern caused by structural vibration.

Since the Bess Avenue POC is certainly a long-span pedestrian bridge, 3D structural analysis was conducted with SAP2000 to ensure that it provides sufficient stiffness against unwanted vibrations. A special through-truss—247.5 ft long, 11.5 ft high and 11 ft wide—was used as the main bridge element (with spans of 80 ft and 157 ft, divided by a concrete pier between the westbound and eastbound/HOV lanes) and a 5.2-ft-deep concrete box girder superstructure was used for the two approach ramp structures. Members include HSS12×12×⅝ for the top and bottom chords, HSS8×6×½ and HSS8×8×½ for the vertical struts, HSS5×5×½ for the top strut and HSS6×4×½ for the bottom strut.

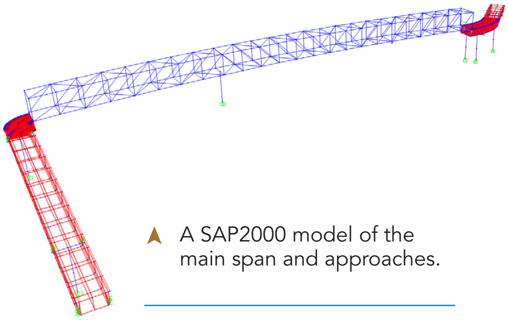
Due to the bridge's location in a high-seismic zone (M=7.5), plus the irregular geometry of the bridge's layout, the complex nonlinear response may dominate the structural dynamic behavior in an earthquake event, which cannot be accurately predicted by elastic modeling. Based on the

The bridge accommodates a widened I-10.

Caltrans Seismic Design Criteria (SDC), a balanced design strategy was employed for the seismic design. The structure was divided into three portions, isolated by expansion joints and designed to act independently to accommodate out-of-phase movements between them: the concrete box girder superstructure for two approach ramp structures and the steel truss for the main portion spanning over I-10. The steel truss was supported by a spherical fixed bearing on Bent 5 and steel-reinforced elastomeric bearing pads with anchor bolts on both ends; these supports provide extra stiffness.

The truss was built via the accelerated bridge construction (ABC) method, which eliminates falsework and minimizes the impact on traffic during construction. It was erected in two phases; the first segment was erected over Bent 5 in a six-hour window and the remaining portion was erected in a second six-hour window and spliced with the first segment.

Using approximately 100 tons of steel, the bridge now serves as a welcoming gateway for Baldwin Park and provides better access to the town center from the residential areas on the opposite side of the highway. ■



A SAP2000 model of the main span and approaches.

Owner and Structural Engineer
California Department of Transportation

General Contractor
Flatiron West, Inc., San Marcos, Calif.

A properly installed coating system adds not only protection to fabricated structural steel, but also value.

product focus

SPECIFYING VALUE

BY WILLIAM D. CORBETT

ON THE surface (pun intended), applying a protective coating to structural steel may seem like a pretty simple procedure.

In reality, a properly applied coating system encompasses quite a bit: surface and edge preparation; abrasive blast cleaning to SSPC-SP10/NACE No. 2, *Near-White Metal Blast Cleaning* and the associated indirect requirements, including abrasive cleanliness and compressed air cleanliness as well as solvent cleaning per SSPC-SP 1; coating materials and associated thinners; mixing and application of sophisticated, multi-component, multi-layer coatings; masking of connections; dry film thickness consistency; cure times and handling; and time allowances for owner quality assurance inspection.

Sophisticated Coating

Given everything involved in the application of a sophisticated paint system, how can you ensure it's done properly? In 2010, AISC and SSPC published AISC-420-10/SSPC-QP 3—*Certification Standard for Shop Application of Complex Protective Coating Systems*. By specifying AISC-420-10/SSPC-QP 3 as a bid requisite, facility owners can have confidence that the corrosion protection system they are paying for is being installed by a shop that has proven its capabilities to an outside auditor.

I've heard people ask, "Why go to the trouble and expense of writing a coating specification when all the information needed is on the manufacturer's product data sheets?" It's important to remember that these sheets contain *recommendations*; they are not intended to act as a specification. Product data sheets often contain multiple surface preparation and coating thickness recommendations based on the intended service environment. They are not prepared for entire coating systems (just single products) and they do not contractually invoke inspection (quality control) check points or the frequency in which these tests must be performed. It is best to think of a product data sheet as simply an "instruction manual" for a coating. It tells us how to mix the product, what to reduce it with, what equipment can be used to apply the product and under what conditions the product can be applied and cured. While relying on manufacturer product sheets to convey the contractual requirements of a sophisticated paint system is cheaper up front, it can become very expensive when poor quality is the end result.

Verifying Quality

Acknowledging that specifying (and verifying) quality will greatly reduce the opportunity for coating problems after the steel is erected, the question then becomes: Which specific quality control checkpoints should be invoked by specification, and how is quality to be verified?

First and foremost, a fabrication shop that applies a sophisticated paint system should have and implement a written quality control program. The written program should incorporate management responsibilities related to quality, technical capabilities of the shop, training of shop personnel, implementation of process controls, internal auditing, purchasing procedures, evaluation of subcontractors and suppliers, calibration and use of inspection equipment and quality control inspection procedures. The program should also contain standard forms for documenting these items as well as the results of project-specific quality inspections. If the shop is AISC-420-10/SSPC-QP 3 certified, they have all of the above. Specifications may also require the shop to prepare and submit a project-specific work plan and quality control plan, based on the corporate plan.

Below are some common in-process quality control check points that can be specified and subsequently verified in the shop, as well as some of the more modern inspection instrumentation that a shop can use to streamline quality control inspections and documentation practices.

Measuring ambient conditions and surface temperature. The prevailing conditions of air temperature, relative humidity (the ratio of moisture in the air relative to total saturation), dew point temperature (the temperature at which moisture condenses on a surface) and the temperature of the steel surface are all important attributes and must be measured and recorded (in the area where the coatings will be applied) prior to mixing the coating and throughout the application process. Most coating manufacturers indicate, on the product data sheets, the acceptable air and surface temperature ranges—a minimum, maximum or acceptable range for relative humidity—and that the surface temperature should be a minimum of 5 °F higher than the dew point temperature to preclude condensation. Specifying a *minimum* amount of moisture in the air is an important

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consideration for coatings that use moisture to cure (e.g., ethyl silicate inorganic zinc primers and moisture cure urethane products). Specifying a *maximum* amount of moisture in the air is an important consideration for coatings that are adversely impacted by excessive humidity during application and cure (e.g., epoxy and polyurethane). While a manufacturer may indicate that a minimum of 40% relative humidity is acceptable, a coating specification can require a minimum of 50% humidity to attain proper cure of a moisture cure product. Similarly, a product data sheet may indicate that up to 90% relative humidity is acceptable; however, the coating specification can invoke a maximum of 85% relative humidity. Ambient conditions and surface temperature can be measured and auto-logged using electronic (digital) psychrometers (Figure 1).

Pre-Blast Ceaning Inspections

Pre-blast cleaning inspection check points include verifying that the abrasive is clean, the compressed air is clean and dry and the grease, oil and other lubricants used during the fabrication process are removed. Note that each of these checkpoints is automatically invoked when an SSPC surface cleanliness standard, such as near-white, is specified (i.e, these are "indirect" requirements of the SSPC *Surface Cleanliness Standards*). These inspections are described below.

Abrasive cleanliness. There are two primary concerns related to contamination of the abrasive media: oil and elevated conductivity caused by soluble salt contamination. The transfer of either of these contaminants onto the steel during cleaning can adversely impact the performance of the coating system; testing is particularly important when the abrasive is recycled. The procedure described in ASTM D7393, *Standard Practice for Indicating Oil in Abrasives* can be specified to verify that the abrasive is not contaminated with oil (Figure 2).

The procedure described in ASTM D4940, *Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives* can be specified to verify that the abrasive does not contain elevated levels of ionic contamination (Figure 3).

Compressed air cleanliness: Anytime compressed air is used to propel the abrasive during blast cleaning, perform a blow-down to remove surface dust or atomize a coating (e.g., conventional/pressure pot spray), its cleanliness must be verified—i.e., do not assume that the moisture and oil extractors are providing adequate air cleanliness. The procedure described in ASTM D4285, *Standard Test Method for Indicating Oil or Water in Compressed Air* can be specified to verify that the compressed air does not contain water and oil contamination (Figure 4).

Grease/oil removal: Prior to mechanical methods of surface preparation (e.g., abrasive blast cleaning), surfaces must be visually inspected to verify that there is no visible grease, oil lubricants or cutting compounds on the steel surfaces that may contaminate abrasive media or be spread across adjacent surfaces. SSPC-SP 1, *Solvent Cleaning* is an indirect requirement of the SSPC Surface Cleanliness Standards (Figure 5). Inspection of surfaces can be performed visually, by wiping the surfaces with a cotton cloth, using black light florescence or using a water break test. There are no ASTM standards governing this type of inspection; however, it is nonetheless a critical inspection checkpoint.

Post-Blast Cleaning Inspections

After surface preparation is completed, there are two primary inspections that must be performed prior to primer application: an inspection for surface cleanliness and surface profile and a visual inspection of the prepared surfaces for residual dust and abrasives. These inspections are described below.

Fig. 1

Courtesy of DeFelsko Corporation

Fig. 2


Courtesy of KTA-Tator, Inc.

Fig. 3 (above) and Fig. 4 (below)


Courtesy of KTA-Tator, Inc.

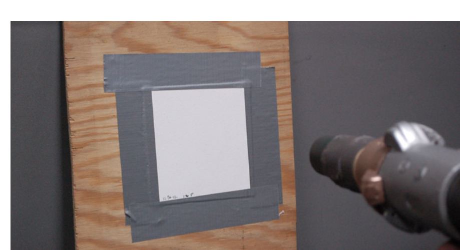

Courtesy of KTA-Tator, Inc.

Fig. 5

Assessing surface cleanliness. SSPC and NACE International have jointly published surface cleanliness standards. The two most commonly specified for shop steel include SSPC-SP 6/NACE No. 3, *Commercial Blast Cleaning* and SSPC-SP 10/NACE No. 2, *Near-White Metal Blast Cleaning*. Both of these standards require 100% removal of all mill scale and rust (and paint, if present). SSPC-SP 6 allows up to 33% staining to remain on each 9 sq. in of prepared steel, while SSPC-SP 10 allows up to 5% staining to remain on each 9 sq. in of prepared steel. Verifying either of these levels of surface cleanliness can be challenging, so SSPC created a visual guide (SSPC-VIS 1; Figure 6) containing color photographs of seven initial conditions (rust grades) of steel (four uncoated and three coated) and various degrees of surface cleanliness for each of the initial rust grades, including SSPC-SP 6 and SSPC-SP 10. The visual guides are used to "calibrate the eye" before evaluating surface cleanliness. While the written standard is the governing document, the specifier can invoke the use of SSPC-VIS 1 for the inspection of the prepared surfaces.

Measuring surface profile. Surface profile "anchors" the coating system to the steel, and the depth of the surface profile must be compatible with the coating system. A surface profile that is too shallow can result in loss of adhesion, while excessive surface profile can result in pinpoint rusting of rogue peaks or the consumption of more paint to fill the profile in order to prevent pinpoint rusting. To this end, a minimum and maximum surface profile must be specified; the specifier may also elect to specify the shape of the surface profile (e.g., "angular"). The size of the abrasive media should not be specified; rather it is the responsibility of the shop to determine the proper abrasive size in order to achieve the required surface profile depth.

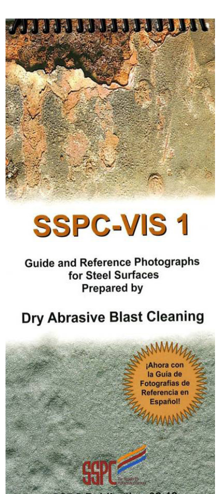
There are two standards for the specifier to consider. ASTM D4417, *Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel* and SSPC-PA 17, *Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements* are designed to be used in conjunction with one another. ASTM D4417 describes how to acquire measurements while SSPC-PA 17 contains requirements for frequency and location of instrument readings and evaluation criteria to ensure that the profile over the entire prepared surface complies with the project specification (Figures 7, 8 and 9).

Assessing residual surface dust/abrasive. Residual dust and abrasive media that remain on steel surfaces after abrasive blast cleaning is performed must be removed prior to primer application (typically by blowing-down with clean, dry compressed air; vacuuming can also be effective) to prevent loss of adhesion as well as coating defects (pinholes). Oftentimes specifications will require a "dust-free" surface, which is essentially impossible to achieve (or for that matter, verify). The most common method of assessing surface dust is not covered by a standard and involves wiping a lint-free clean cloth across the surface and visually observing the surface for "swipe marks." When swipe marks are no longer discernible, the surface is considered ready for primer application. Alternatively, a specifier may elect to invoke ISO 8502, Part 3 – "Assessment of Dust on Steel Surfaces Prepared for Painting," which incorporates the use of a clear adhesive tape that is pressed onto the surface and removed. The tape is compared to a rating chart that illustrates five levels of surface dust. Dust size can also be comparatively rated by this method, although arguably less important. Naturally if this method is invoked, the acceptable level of dust must also be specified.

Coating mixing, thinning and application inspection. In this case, a review of the manufacturer's product data sheets, combined with observation, is the best "tool" available to verify that the coating materials are being mixed, thinned and applied properly


Courtesy of KTA-Tator, Inc.

Fig. 6



Courtesy of KTA-Tator, Inc.

Fig. 7

Courtesy of KTA-Tator, Inc.

Fig. 8

Courtesy of KTA-Tator, Inc.

Fig. 9

Courtesy of KTA-Tator, Inc.

Courtesy of KTA-Tator, Inc.

Courtesy of Fischer Technologies, Inc.

◄ Fig. 10

► Fig. 11

(Figure 10). In fact, coating specifications often invoke the PDS for mixing and thinning instructions. PDS' also contain recommendations for compatible application equipment, spray pressures, tip sizes, etc. Note that the thinner type and amount is considered an essential variable by the *Specification for Structural Joints using High Strength Bolts*, Appendix A—"Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints," published by AISC and the Research Council on Structural Connections (RCSC). Consideration should be given to this when connections are slip-critical. The minimum cure time, coating thickness and thinner type/amount are all listed on the test certificate prepared by the testing laboratory. The certificate can typically be provided to the shop by the coating manufacturer.

Dry film thickness. Achieving the specified thickness of each coating layer is perhaps one of the more challenging tasks for an applicator, particularly when complex elements are being coated. Measurement of coating thickness is governed by two standards: ASTM D7091, *Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals* and SSPC-PA 2, *Procedure for Determining Conformance to Dry Coating Thickness Requirements*. Like surface profile measurement, the two standards are designed to be used in conjunction with one another. The ASTM standard focuses on gage use (Figure 11), while the SSPC standard focuses on the frequency of coating thickness measurement, the acceptability of the measurements and how to handle nonconforming areas of thickness. Appendices 2 and 3, while not mandatory, provide methods for measurement of coating thickness on steel beams (girders) and for a laydown of beams, structural steel and miscellaneous parts after shop coating. The appendices can be invoked by the specifier if desired; otherwise the frequency of measurement is based on 100-sq.-ft areas. Note that the current (2012) version of SSPC-PA 2 contains a chart listing five "Coating Thickness Restriction Levels." Each level provides a tolerance for gauge readings (each individual gauge measurement), spot measurements (the average of five gauge readings within a 1.5-in. circle) and area measurements (the average of five spot measurements over 100-sq.-ft areas). If the level is unspecified, then Level 3 becomes the default (gauge readings unrestricted; spot measurements +/- 20% of the specified thickness range; area measurements within the specified range). The tolerance of the spot measurements for Levels 1 and 2 are more restrictive, while levels 4 and 5 are less restrictive. Also, if the specifier does not establish an acceptable range of thickness for each coating layer (and the manufacturer does not indicate a range on the PDS), the range (minimum and maximum thickness) is established at 20% of the target thickness.

Curing. Drying, dry-to-recoat and curing are not the same, especially when it comes to industrial protective coatings. For example, inorganic zinc-rich primers (commonly used in the shop) dry very quickly, especially in a heated shop. However these primers need moisture to cure, so topcoating them when they appear to be dry but before adequate dry-to-recoat times are achieved can result in catastrophic delamination failure. Depending on the conditions in the shop and the coating type, it may take 18 to 24 hours or more (even a few days) before an applied coating has achieved an adequate dry-to-recoat condition. (For ethyl silicate inorganic zinc-rich primers, the coating manufacturer may permit misting with water or steam—after an initial cure for a few hours—to keep the coated surface wet for a minimum amount of time, in order to accelerate curing or to promote curing when the relative humidity is too low.) Solvent rub tests and hardness tests can be used to verify that coatings are dry-to-recoat and can withstand the solvents and contractive curing stresses of subsequent coating layers. ASTM D5402, *Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs* can be used on convertible coatings like epoxy and urethane, while ASTM D4752, *Standard Practice for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub* was written specifically for assessing the cure of inorganic zinc-rich primers. Pencil hardness (ASTM D3363) is referenced by some coating manufacturers to assess the hardness of the applied coating. In this case, a minimum hardness value is used as an indication of adequate dry-to-recoat condition or cure. (Note that full curing of some coatings can take weeks or months to achieve, but the coating is serviceable during this time.)

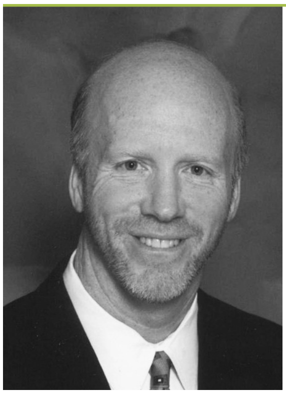
Specifying quality and verifying quality workmanship (i.e., specification compliance) helps reduce the opportunity for premature coating breakdown and/or failure of the corrosion prevention system. Despite what can seem to be a higher up-front cost, facility owners should recognize the value and long-term benefits that come with preparing a well-written specification and contracting with a fabrication shop that embraces quality. Specifying an AISC-420-10/SSPC-QP 3 certified shop is a step in the right direction. ■

Emergency steel spans reopen
an Interstate river crossing shortly after a bridge collapse.

QUICK Thinking

BY WILLIAM KILLEEN, P.E.

▲ The north span of the Skagit River Bridge, following the collision.



William Killeen (**wtkilleen@acrowusa.com**) is president and CEO of Acrow Bridge.

IT WAS THE THURSDAY EVENING before Memorial Day weekend of 2013 when the unthinkable happened.

As western Washington commuters headed home and vacationers got underway via Interstate 5 about 60 miles north of Seattle, a southbound truck hauling an oversized load shifted to the right as it crossed the Skagit River Bridge, causing the load to strike the overhead parts of the bridge. Within moments, the damaged north span of the bridge collapsed, carrying with it numerous vehicles and their drivers and passengers into the river below. Fortunately, the accident did not result in any loss of life, but Washington State Department of Transportation (WSDOT) now had to find a quick and safe solution for resolving a connectivity disaster with significant negative financial implications in the making.

I-5 is the main interstate highway on the West Coast of the U.S., stretching from Canada to Mexico and connecting several major cities, including Vancouver, Seattle, Portland, Sacramento, Los Angeles and San Diego. The commercial and passenger traffic that this critical transportation artery carries on a daily basis is enormous. The I-5 Skagit River Bridge has four main spans of 160 ft each and is part of the primary route connecting Vancouver and Seattle, with an estimated 71,000 vehicles crossing the steel through-truss bridge every day. Its collapse created a transportation nightmare with immediate financial impact; a nearby Costco alone reported a loss of $1 million in one day as a result of the collapse.

Temporary spans were erected, and the bridge reopened only 23 days after the collapse.

Erection of the temporary spans.

Crisis Averted

Clearly, a solution needed to be developed and commissioned as quickly as possible to stem the losses in business and tax revenues as well as the disruption to daily life and its widespread consequences. Different options were considered for the reopening of the river crossing, and in the end, WSDOT selected a bridging solution of prefabricated modular steel, which could be mobilized and assembled with great speed while providing the strength and durability demanded.

WSDOT awarded Atkinson Construction the emergency construction contract two days after the incident, and Acrow Bridge, a fabricator of modular bridges, became part of the team charged with engineering a rapid solution for bridge replacement. Acrow supplied two modular, prefabricated steel panel bridges. Each bridge weighed 180 tons, with clear spans of 160 ft and road widths of 24 ft, to replace the damaged section of the bridge. Modular steel orthotropic deck sections, which were overlaid with asphalt, were used for the roadway, and heavy-duty crash barriers were installed on each side for driver safety.

Acrow bridges are all-steel bridges composed of smaller components that pin and bolt together. All of the bridge components are available on a COTS (components off the shelf) basis and can be rapidly mobilized. With all components prefabricated and requiring no field welding, the bridges can be rolled into position with or without the use of sophisticated equipment, including a crane. This became an important factor in the Skagit River Bridge installation, as no suitable crane was available at the time for a lift-in of the spans. A crane-assisted launch was also not possible, as the existing multi-span through truss was an obstruction. The only workable approach for putting the emergency bridges into place was by rolling each bridge across the gap in full cantilever, balancing each span like a large playground seesaw, without the use of a crane.

To facilitate the installation, the bridge pedestals were designed to allow for the sliding of the bridges sideways on Hilman rollers, which was necessary because the existing through truss was 8 ft narrower than our structures. Once the pedestals were in place, the first bridge (northbound lanes) was rolled into place, jacked down onto the rollers, moved eastward, cantilevered over the bridge pedestals and positioned out of the way to make room for the second bridge (southbound lanes). The second bridge was jacked down and positioned on permanent bridge bearings, 6 in. from the first bridge, and the deck was then situated and asphalted.

Speed and Service

We coordinated our response to the emergency through our local office and depot in Camas, Wash. When we first learned of the collapse, we made the decision to send eight truckloads of Acrow prefabricated bridge steel to the project site that would be used to construct the bridge spans—even though a contract to supply the bridges had not yet been awarded—as we thought it would be best to have everything in place for quick assembly.

We also deployed field technicians to work side by side with the WSDOT and Atkinson Construction team. The technicians were a critical element in our ability to deliver a bridging solution within a very tight time frame, working closely with our engineers at our corporate headquarters in New Jersey and the engineers at Atkinson. Everyone worked around the clock to assemble the emergency bridges and roll them out across the Skagit River. The highway bridge was formally reopened in June, only 23 days after the collapse of the damaged span. The Acrow spans were in place until mid-September when the permanent spans were installed via a roll-out/roll-in method. The Acrow bridge was then disassembled and shipped to the company's storage yard in Washington. Later in the year, almost all of these components were shipped to California as part of a planned detour bridge. ■

Owner and Structural Engineer
Washington State Department of Transportation

General Contractor
Atkinson Construction of Renton, Wash.

Steel Fabricator and Detailer
Acrow Corporation of America, Parsippany, N.J. (AISC Member)

Deon Lourens/Acrow

▲ Two 160-ft spans, weighting 180 tons each, were installed via Hilman rollers.

Philadelphia FALLS

BY JIM TALBOT

A Victorian-era landmark over the Schuylkill River, the Falls Bridge plays a prominent role in its Philadelphia neighborhood nearly 120 years after its opening.

STEEL CENTURIONS
SPANNING 100 YEARS

Our nation's rich past was built on immovable determination and innovation that found a highly visible expression in the construction of steel bridges. The Steel Centurions series offers a testament to notable accomplishments of prior generations and celebrates the durability and strength of steel by showcasing bridges more than 100 years old that are still in service today.

MANY IN PHILADELPHIA may wonder how the Falls Bridge over the Schuylkill River got its name; there are no falls in the vicinity.

Back in the early 1800s, however, a natural waterfall did exist at the site, now known as the East Falls section of the city (girlhood home of Grace Kelly). But an overflow dam built downstream in 1821 backed up the river for six miles, covering up the falls and inundating some islands in the river. The dam ponded the river for the local water supply as well as hydropower; to this day, it continues to provide water storage for two pumping stations with river intakes. The dam also tamed the river, making it ideal various recreational activities, including sculling, regattas and canoeing.

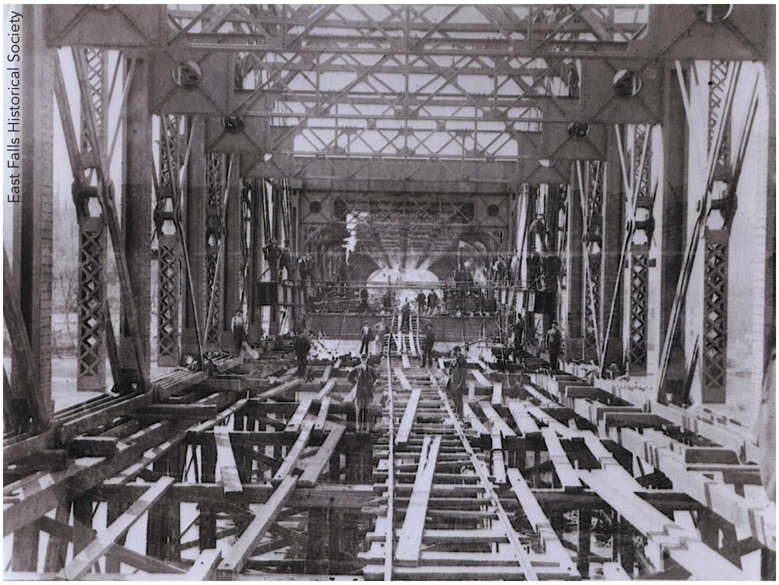
Permanent Replacement

The Falls bridge, completed in 1895, replaced several predecessors that were destroyed by a variety of causes: overloading, floods and fire (flood waters lifted the earliest one, a covered bridge, off its piers and floated it down river in spectacular fashion). These early bridges carried workers and materials to major factories on the west side of the river. The community greatly celebrated the bridge opening in June 1895 because it provided a much needed link between the two sides of the river. Originally, flamboyant paint colors of red, buff and light blue made the bridge a striking sight.

Today, the Falls Bridge still serves as a vital link in Philadelphia's transportation system, connecting Kelly Drive (formerly East River Drive) with Mar-

Photo: Ryan Linton; Lighting Design: GWA Lighting

▼ The bridge, under construction. It was completed in June of 1895.



East Falls Historical Society

tin Luther King Jr. Drive (formerly West River Drive). Both drives take commuters from the north in and out of the city. At last count (1981) the bridge still carries 1,300 vehicles per day on average.

Filbert Porter and Company built the Falls Bridge at a cost of $262,000. At the time, James H. Windrim served as the director of public works and George S. Webster as the chief engineer. The bridge has a total length of 566 ft and its longest span is 192 ft. The 41-ft-wide deck provides two lanes for traffic as well as pedestrian walkways on each side. The deck is a closed grating with a bituminous wearing surface; overhead clearance reaches 16.4 ft.

Two piers and abutments of stone masonry, built on solid bedrock, form the substructure. These supports were started nearly ten years prior the bridge's completion.

The superstructure divides into three connected spans, each nearly 190 ft in length. Each span is a modified steel Petit (Pennylvania) through-truss having eight panels and riveted and pinned connections. The Pennsylvania Railroad pioneered the Petit truss design for bridges, which was popular through the 1920s; it's a variation of the Pratt truss, characterized by diagonals that slope down toward the middle of the truss. A Petit variation adds half-length struts or ties within a panel. In this case two struts connect a panel's center diagonally to the upper chord and horizontally to one side.

The vertical compression members that define the panels combine steel plate and steel angles with continuous riveted connections. Eye bars resist tension forces in the diagonals and the bottom chord. Built-up lateral plate girders serve as the floor beams that support the deck roadway. A pair of longitudinal stringers connects the floor beams.

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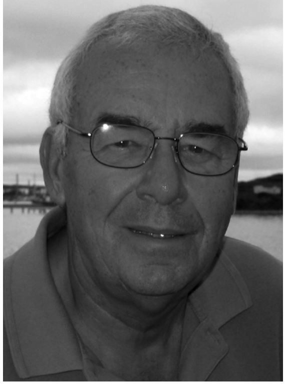
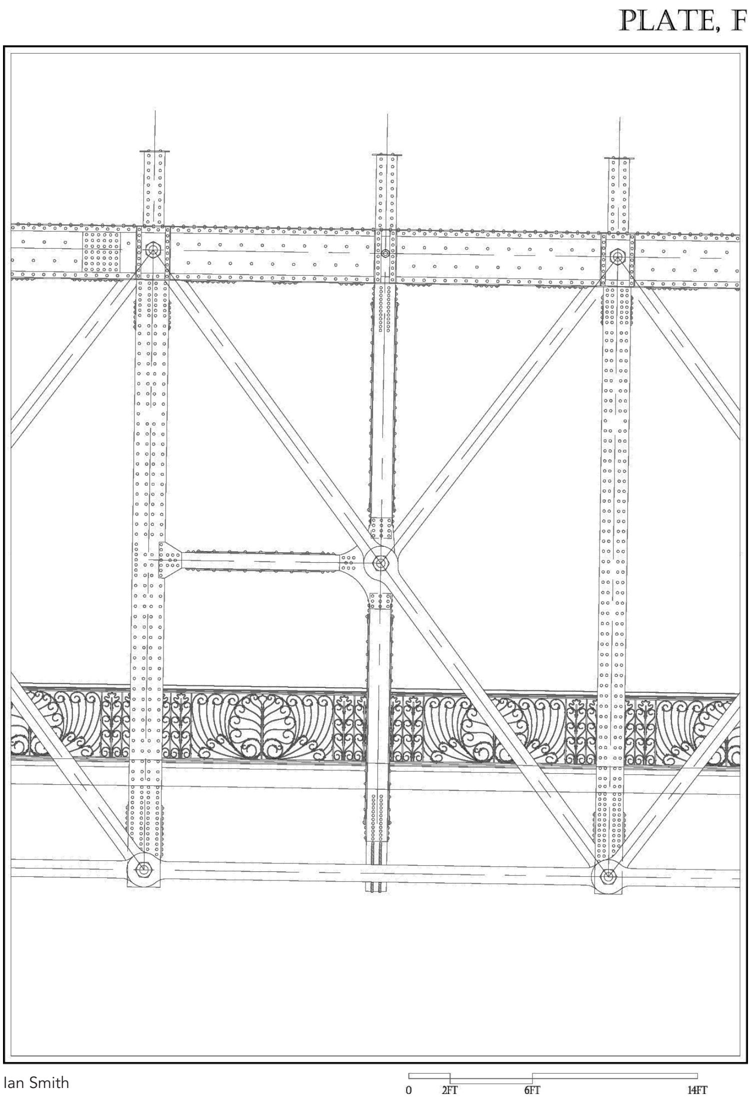




Ian Smith

An engineering drawing of one of the bridge's truss panels (from Ian Smith's *The Connections of Mechanical Fasteners*).

The original plan called for an upper deck to support a roadway and a two-way railroad track. The existing heavy upper bracing would have served as the floor beams for the upper deck, which was never built. The need to acquire more land and to displace existing structures on approaches, along with estimates for further work on the upper deck, would have exceeded the $300,000 appropriated by the city.

The railing consists of stock iron 5⁄16 in. by 1.5 in. The iron is wrought into a decorative curvilinear pattern that repeats twice across each panel, and the pattern has a centered medallion with curved scrolls reaching upward on each side. Two vertical vine-like structures on each end complete a repeated pattern.

The Falls Bridge continues to serve Philadelphia and the East Falls community. Participants in the annual Philadelphia Marathon cross the bridge during their run. An eight-mile loop of the Schuylkill River Trail that runs on both sides of the river between East Falls to the Philadelphia Art Museum crosses the river at the Falls Bridge. The loop is a scenic recreational path for walkers, joggers, bicyclists and rollerbladers.

Hitting a Hundred

The community held a Centennial celebration of the bridge in June of 1995. Festivities included postmark cancellations (graphics were done by local artist), a fishing contest, a regatta and sculling demonstrations. Kids got pony rides while adults rode horse-drawn carriages across the bridge. Local groups provided singing and dancing during the day followed by a band concert in the evening, and businesses and residents contributed to a fund to provide bridge lighting in the future.

That future arrived in January 2008 with a lighting ceremony attended by 500, including then-Governor Rendell, the late Senator Arlen Specter and Philadelphia Mayor Nutter. Rendell, an East Falls resident for 28 years, said he had long been a huge fan of the bridge, and after a countdown he and Mayor Nutter triggered the initial bridge lighting. The crowd cheered while white lights flooded the side of the bridge, and blue LED lights atop each of the main vertical members blinked on.

In September of 2011 the East Falls Development Corporation sponsored the First Annual Dance on the Falls Bridge, an event that has continued annually ever since. A silent auction usually benefits a local charity. Proceeds from ticket sales for the dance also help to improve the East Falls neighborhood streetscapes, signage and business development. ■

Wendy Moody, East Falls

Crossing the Falls Bridge during its 100-year celebration.

conference preview

INCREASING SPANS AND POSSIBILITIES

BY DUSTEN OLDS, P.E., PHILIP ROSSBACH, P.E., AHMAD ABU-HAWASH, P.E., LANCE PETERMAN, S.E., P.E., AND BRANDON CHAVEL, P.E., PH.D.

Two bridge projects show what's possible with a long-span I-girder scheme.

THE USE of steel I-girder bridges for spans exceeding 450 ft can be a cost-effective solution in today's market. Two bridge projects, one over the Missouri River and the other over a canal adjacent to the Mississippi River, demonstrate this.

U.S. Highway 34

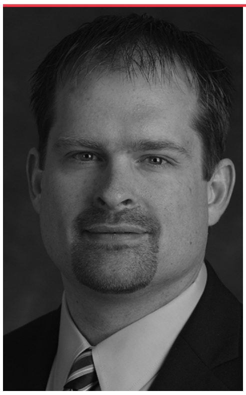
Efforts to upgrade U.S. Highway 34 as it crosses the Missouri River between Iowa and Nebraska called for a new bridge just south of Omaha. The 3,276-ft-long structure, currently under construction and scheduled to be completed late this year, includes a 1,297-ft-long, three-span main river unit (391 ft, 515 ft and 391 ft) that uses a haunched steel girder with a substringer system. The cross section of the main river unit consists of five haunched steel plate girders spaced at 20 ft, 6 in. with substringers located in the middle of each bay.

With any steel girder bridge design, the engineer is faced with deciding the appropriate level of analysis for final girder design and which analysis will produce acceptable preliminary design sizes. Girder design forces are dependent on a complex behavior of load transfer and geometry in three dimensions. For this project, a 3D finite element model (FEM) was developed for analysis and final design. These results were compared to a preliminary line girder analysis.

The range of applicability of the AASHTO LRFD approximate live load distribution factors is constrained by the original research and development of the approximate equations. The girder and substringer superstructure configuration, which is typically used for long-span structures, would inherently exceed the specification limits for the span length, beam spacing and stiffness criteria.

Until further research is established to substantiate the applicability of the LRFD approximate equations beyond the current limits, a more sophisticated analysis is required. However, the use of the equations for preliminary design and initial girder sizing is of real interest to design engineers. Based on this analysis, the LRFD approximate factors resulted in reasonable correlation to the 3D results for this structural system. While further research would need to be performed to allow use of the LRFD approximate equations in final design of this structure type, the LRFD specifications can be reliably used for preliminary sizing.

The size of the field sections required ready barge access for transport to the project site. With haunched girder web depths up to 24 ft and field sections ranging up to 135 ft long, some sections weighed up to 150 tons. Handling the girders efficiently became the biggest shipping challenge on this project. Laser





Dusten Olds, P.E. (dusten.olds@hdrinc.com) is a professional associate and bridge engineer at HDR and served as structural engineer for the U.S. 34 Bridge over the Missouri River. **Philip Rossbach**, P.E. (phil.rossbach@hdrinc.com) is a vice president and senior project manager with HDR and served as project manager for the U.S. 34 Bridge. **Ahmad Abu-Hawash**, P.E. (ahmad.abu-hawash@dot.iowa.gov) is the chief structural engineer for the Iowa Department of Transportation. **Lance Peterman**, S.E., P.E. (lance.peterman@hdrinc.com) is a professional associate and senior project manager for HDR and served as structural project manager for the I-270 Bridge over the Chain of Rocks Canal. **Brandon Chavel**, P.E., Ph.D. (brandon.chavel@hdrinc.com) is a professional associate and bridge engineer with HDR and served as lead bridge engineer for the I-270 Bridge.

A drop-in segment for U.S. Highway 34.

All images: HDR

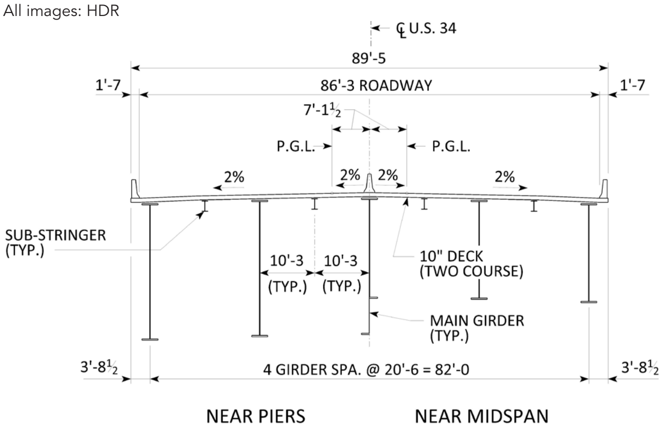
scanning equipment was used during girder laydown to fabricate customized field splice plates and helped to eliminate fit-up problems during girder erection. In addition, general contractor Jensen Construction built a scale model of the main river unit in its office to help plan their erection sequence.

The company used two 300-ton cranes mounted on barges to perform the main span girder erection. The crane limitations were a concern with the size of the field sections. The boom distances combined with load shifting due to listing of the barges pushed the cranes near the load chart limits. However girder erection progressed smoothly and the total duration for steel girder erection of the main river unit was approximately three months.

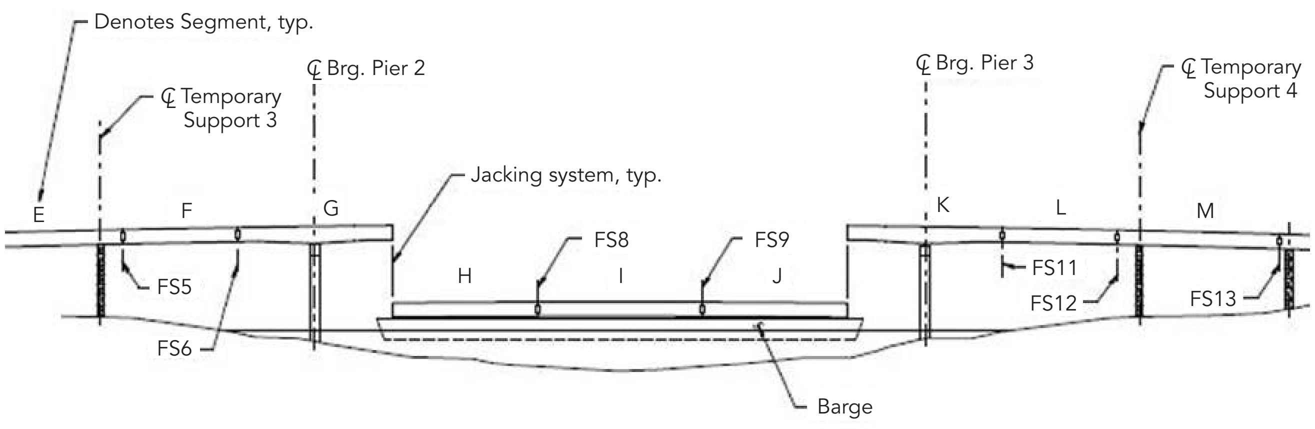
Owners
Iowa Department of Transportation (Lead)
Nebraska Department of Roads

Structural Engineer
HDR, Omaha

General Contractor
Jensen Construction Co., Des Moines



UNIT 2 TYPICAL SECTION



The center span strand jack lift for I-270.

I-270 Bridge

I-270 is a four-lane interstate expressway that serves as a north bypass to St. Louis and carries an average of 54,700 vehicles per day between Illinois and Missouri. This project included the replacement of a pair of truss bridges over the Chain of Rocks Canal adjacent to the Mississippi River, with a single steel I-girder bridge on a new alignment just north of the existing bridges. The Chain of Rocks Canal provides a bypass for all Mississippi River barge traffic in the region and is necessary due to the rock outcrop in the portion of the river in the vicinity of I-270. On average, more than 70 million tons of cargo per year passes through the canal, making it the busiest navigation area on the Mississippi River.

The United States Coast Guard (USCG) required that the bridge provide a 350-ft horizontal navigational clearance and that the 50-ft vertical clearance match what was provided by the existing I-270 bridges. A reduction in the 350 ft horizontal clearance, to 200 ft, was permitted by USCG during construction. These temporary horizontal clearance requirements were considered when determining the main span length of the new bridge. A continuous steel plate-girder bridge was evaluated as the most economical and best in terms of structural redundancy, seismic performance and maintenance and inspection categories.

➤ Storing girders for I-270.

The new 1,970-ft-long bridge consists of five continuous spans: 250 ft, 440 ft, 490 ft, 440 ft and 350 ft; the span arrangement was dictated by the need to span the canal and adjacent east flood protection levee. The bridge is 94 ft, 2 in. wide and can accommodate a future lane arrangement of six total lanes. It consists of 10 variable depth steel plate I-girders, and given the amount of steel required, the design strived to achieve economy with regard to material, fabrication and construction.

Flange plate thicknesses are repeated throughout the structure as much as possible, in an effort to reduce the number of plate thickness sizes required to be procured by the fabricator. Flange plate transitions were limited to field splices only, except for a flange plate transition on each side of each interior pier. A thicker web is used at the support locations in order limit the number of stiffeners required. Grade 50W and HPS70W steel is used in the structure.

➤ The steel superstructure of I-270 before the last lift.

▲ Girder web depth transition at Pier 1 of the I-270 bridge.

➤ Top flange lateral bracing for the bridge.

Variable-depth girders are employed to reduce the amount of web material and also to provide appropriate girder depth for the required demands. The web depth transitions at Pier 1 and the girders are haunched at the main canal piers. Straight-line depth transitions are used to simplify the girder fabrication and reduce fabrication costs.

Intermediate and pier cross-frames are an X-type shape, due to girder spacing and girder depth that provide a mostly square shape for the cross frame; WT sections are used for all cross frame members. Based on the 3D finite element method (FEM) analysis, the cross frames are subjected to dead, wind, thermal and live load and seismic demands, as well as forces due to a future part-width deck replacement.

Top flange lateral bracing, consisting of WT sections, is used in the exterior girder bays along the entire length of the bridge and is required while the bridge is being constructed. The top flange lateral bracing prevents excessive lateral movement due to wind at intermediate stages of steel erection and also prior to and during placement of the concrete deck. Additionally, in each span, the steel erection begins with a twin girder system. The top flange lateral bracing adds torsional stiffness and increases global buckling resistance of the initial twin girder systems during steel erection.

Construction began in October 2011. Steel girders started being delivered in July 2012 and were placed at a local storage yard near the project site. Steel erection began on the west side of the bridge, before the completion of Piers 3 and 4 on the east side of the canal; the first girders were set in November 2012. Three separate center span strand jack lifts occurred between mid-October 2013 and early November 2013. Girder lines and cross frames were constructed on a nearby floating barge and then moved into place below the steel superstructure, then strand jacks were used to lift the assembly into place. This method of construction reduced the closure window of the canal to under 24 hours. The new I-270 bridge is expected to open to traffic this summer. ■

Owner
Illinois Department of Transportation

Structural Engineer
HDR, Chicago

Steel Team

Fabricator and Detailer
Stupp Bridge Co. (a division of Stupp Brothers, Inc.) St. Louis (AISC Member/NSBA Member)

Erector/General Contractor
Walsh Construction Co., Chicago (AISC Member/AISC Advanced Certified Steel Erector)

This article serves as a preview of Session B6, "Design of Long-Span Plate Girder Bridges" at the World Steel Bridge Symposium, taking place in tandem with NASCC March 26-28 in Toronto. Learn more about the conference at www.aisc.org/nascc.

A European composite solution provides a viable and economical alternative to concrete girders for short-span bridges.

conference preview

SHORT-SPAN SOLUTION

BY RICCARDO ZANON, JACQUES BERTHELLEMY, GÜNTER SEIDL AND WOJCIECH LORENC

COMPOSITE BRIDGE decks with steel girders and reinforced concrete slabs have proven their competitiveness over the years and have become the standard solution for medium-span bridges in Europe.

In the small-span range, however, traditional deck typologies (such as prefabricated prestressed concrete girders) have long been the most popular solution mainly on the basis of perceived economic, rather than technical, reasons.

In 2003, an effort was launched to change this perception. The main target of this effort, a European research project called Precobeam, was to develop a solution using prefabricated elements that would be price-competitive, durable, suitable for integral bridges and decks monolithically connected to a substructure (in order to minimize maintenance actions) and simple to erect.

SSF Ingenieure AG

A conceptual Precobeam section.

The result is a composite beam with steel T-sections that act as external reinforcement to a concrete top chord. Steel parts are generally obtained from rolled steel profiles that are longitudinally cut, with a special shape, into two T-sections. The special shape of the cut allows for shear transmission between steel and reinforced concrete and is now standardized. It was tested at ultimate, serviceability and fatigue limit states.

This innovative construction method has garnered the interest of bridge owners as well as general contractors thanks to its easy but effective concept. Since it became available, about 20 bridges (roadway, railway and pedestrian) have been built throughout Europe, demonstrating its viability as an alternative for short-span bridge construction.

Advantages Above and Below

The Precobeam concept combines the advantages of prefabricated prestressed concrete beams (the upper T of the section) with the steel girders (the lower T of the section). There are currently two assembly types: Duo-Precobeam and Mono-Precobeam. With Duo-Precobeam, two halved sections are positioned beside each other and filled with

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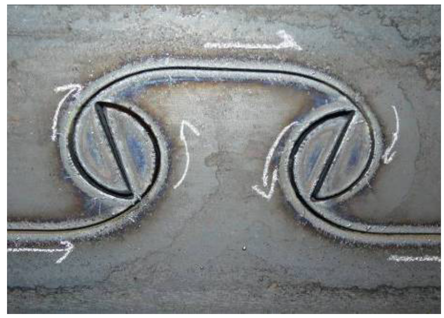
View beneath the Pöcking Bridge (Germany) with Precobeam elements.

concrete, which ensures a consistent torsional inertia, a more slender section and that the shear connection is nearer to the neutral axis. Mono-Precobeam uses only one halved beam and calls for a deeper reinforced concrete web. This option is more similar to a prefabricated concrete section, but with better bending moment resistance thanks to the steel acting as "external reinforcement."

In Use

One such bridge is a 16.6-m-long (54.5-ft), two-span deck with abutments and one intermediate pier between the tracks. The total deck width is 10.5 m (34.5 ft). As the reconstruction was taking place over an existing railway line, a prefabricated solution to minimize trafic disturbance was essential. The entire deck width is supported by only three Precobeam elements. Rolled sections HE1000M in S460M steel grade (equivalent to W1000×300×350 in Grade 65) are cut into two halves and recomposed in small open box girders in full length of 32.5 m (107 ft), and the connection was ensured by composite dowels with puzzle shape.



◄ The cutting pattern of the MCL composite dowel.

◄ Steel fabrication of the Pöcking Bridge.

▼ Finished Pöcking Bridge.

SSF Ingenieure AG

Using Precobeam technology reduced the construction phase significantly, and the three elements were erected in one night. Next, 25 cm (10 in.) of concrete C35/45 was cast in-situ to solidify the three elements, and neither scaffolding nor formwork were needed.

The technology has been also applied to other bridges on Highway S7 in Poland between 2009 and 2012. Wide decks are realized as continous beams over three or four spans, with a maximum span of 18 m/59 ft) with a construction height of 83 cm/2.72 ft (slenderness L/22). Precobeam elements were made out of coupled HE1000A/B/M in S355 (equivalent to W1000×300×272/314/350 in Grade 50) with a slab width of 2.4 m (8 ft), and the prefabrication was done directly on-site by the general contractor. ■

This article serves as a preview of Session B14, "New Structural Forms for Short-Span Bridges" at NASCC: The Steel Conference, taking place March 26-28 in Toronto. Learn more about the conference at ***www.aisc.org/nascc****.*

conference preview

QUALITY AND THE BRIDGE ENGINEER

BY SHANE R. BEABES, P.E.

Handle the increasing complexity in bridge analysis and design with a robust quality management system.

TODAY'S BRIDGES are becoming more complex in order to mitigate constraints like right-of-way, natural resources, maintenance of traffic and economic requirements.

Bridge span lengths are becoming longer, bridge skews are becoming sharper and roadway curvatures are becoming tighter—all of which require more in-depth analysis not only to address strength design provisions, but also predicted performance criteria such as deflections during erection and fit-up.

Couple the complexity of the analysis with more rigorous code provisions—and typically more aggressive schedules for alternative delivery projects such as design-build projects—and the bridge engineer must rely on a quality management system for confidence that the design and contract deliverables will meet the client's needs and expectations, as well as typical industry practice and standard of care.

Quality Management Systems

Requirements for a quality management system (QMS) are specified in resources such as the International Organization for Standardization (ISO) standards. The QMS in general form is outlined in ISO-9001 and may be adapted to many applications. In the context of engineering, companies often use ISO 9001 in developing a quality management system that provides the engineer a roadmap to effectively and efficiently meet the client's needs.

How is quality defined? According to BS EN ISO 9000:2005, quality is the "degree to which a set of inherent characteristics fulfills requirements." A QMS program is set up to "direct and control an organization with regard to quality." Typical terms often used in the bridge industry when it comes to quality include quality assurance and quality control. Although these terms are often used together, they each serve separate and distinct purposes in the QMS process.

Quality assurance and quality control are both integral parts of quality management and are defined in BS EN ISO 9000:2005. Quality assurance focuses on "providing confidence that quality requirements will be fulfilled" whereas quality control "focuses on fulfilling quality requirements."

A key for operating an organization, in this case an engineering firm or agency, is the implementation of a comprehensive QMS. To do this, the system must be designed for continuous improvement. Continuous improvement will increase the likelihood of both enhancing customer (client) satisfaction and meeting their desired requirements. An effective system will promote consistency in the execution of the design process—which is what bridge clients would typically desire.

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Client Requirements

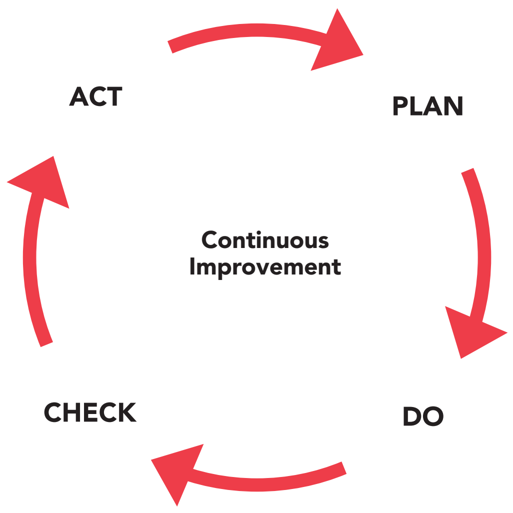
As mentioned earlier, a key component of quality is meeting the client's requirements. In the context of bridge engineering, typical client requirements may include safety, durability, economy, constructability and aesthetics. Due to the consequence of structural failure, defined in this instance as the collapse of a structure, safety is an overarching requirement that transcends the bridge industry. As practicing engineers, not only do we strive to meet our client's requirements, but we also must do so while recognizing industry practice and standard of care.

As engineers, we all take an oath to protect the health and welfare of the public. This is echoed in the American Society of Civil Engineers' Code of Ethics: Canon 1—"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."

It is important to emphasize that a QMS alone cannot protect the health and welfare of the public. The application of sound engineering judgment must be paramount in the design process. Ultimately it is the integration of a QMS with sound engineering judgment that will provide the path to success and reliability in meeting safety requirements.

Quality Assurance and Quality Control

Quality assurance (QA) is successfully implemented as a cyclical process. This cyclical process is described in ISO 9001 as the Plan-Do-Check-Act method of performance improvement, which depicts the feedback loop between customer needs, customer satisfaction and improvement of the internal management system.



The cyclical QA process.

The first step is to document what you plan to do in writing, and then do the work in accordance with the plan while recording the work. Then, check the work that has been performed and act to improve on the process based on what has come out of the review. Essential to the QMS is continuous improvement, which is why it is important to review the work performed. In the Bridge Industry improvement is often based on lessons learned. Sometimes these lessons are taught the hard way, which makes continuous improvement the easier way.

On a project-level basis, QA should cover the process from start to finish—from project initiation through project closeout. During project initiation, the client's contract should be reviewed to understand and make sure the client's requirements are clearly defined. At the same time, staff should be assigned that have the capability to meet the specified requirements. The right staff skill sets for the project will be crucial for a successful outcome.

After review and assignment of staff, a project plan should be developed in written format for distribution to the project team outlining the client's requirements, goals of the project, staff assignments, staff responsibilities, project documentation procedures, client deliverables and intervals for review throughout the design process. In addition, and very important to meeting client requirements, the design criteria for the project should be explicitly outlined including any statutory or regulatory requirements.

The design output for a typical bridge project may include calculations, contract drawings, specifications and reports. The QC process is invoked during the development of these documents. During this process the design output is originated and then independently checked to make sure the approach and the output are technically correct. This check, however, should not be limited to just an arithmetic check of the calculations, but also must include an evaluation of the design methodology and its appropriateness to the element under design. This evaluation is invaluable in the design process and where the input from an experienced engineer is crucial.

The checking process can vary depending on the complexity of the bridge or element being designed. For simple design processes, a line-by-line check of the calculations may be adequate. In more complex bridges, such as highly curved I-girder bridges, an independent design check using a separate model may be the tool used to validate the record design model. The response of the system (interaction of the girders and cross frames) may not be intuitive and will require careful review to understand the behavior of the system. As part of the project plan, a process can be identified up front to address the anticipated complexity by requiring a technical peer review of the design output—whether it is the calculation results and/or the finished plans. Regardless of simple or complex design, the important issue is that the end product meets the client's requirements and the checking is commensurate with meeting this objective.

Inherent to the bridge industry is the use of structural analysis and design software. This can range from in-house spreadsheets with transparent limitations and assumptions to commercially available software. In all cases, these design tools must be thoroughly vetted—which should be part of the QMS.

The bridge industry relies heavily on commercially available software. Typically, the routine design software is considered industry standard or industry adopted. However, who is responsible for the accuracy of the software? In reading the disclaimer on many commercially available software packages, it is left to the user to determine the applicability of the software for use. There is also the inherent undertone that the engineer is responsible for the accuracy of the results. This is an enormous responsibility to be undertaken often under less than ideal conditions. All too often, those not engrained in the analysis and design process think this step is a "push of the button," which couldn't be further from reality. The engineer is obligated to address these challenges associated with software while adhering to industry practice and standard of care.

With the increased complexity of bridges comes the increased complexity in the analysis tools. The use of a line girder model is limited, so there is an increasing use of 2D grid/grillage models as well as 3D finite element models to address the system forces in such cases as highly skewed bridges and curved girder bridges.

The QMS may include such processes as running the software to compare results against known benchmark or published examples, when they exist, or performing hand calculations to check the results before the software is used on a project. However, the validation of the more complex 3D models, and to some degree the 2D models, is not always straightforward. There is the option to run one industry-adopted software against another to compare results, but this too often leads to even more questions. Software typically has different boundary conditions, limitations on member properties such as I-girder torsional stiffness, etc. that makes reconciling member force results and other system behavior more difficult.

The process of software validation is rarely a one-time effort. With the continuous release of new versions of software, it typically puts the engineer in the continuous mode of software validation on every project start-up. Time and effort dedicated on the last project is often lost on the next project. In the end, the process heavily relies on engineering experience and judgment.

As part of the design review, another essential process for a successful project is planning and review for constructability, which is part of the QC process and should be outlined in the project plan. A constructability review may take many forms; consider the concept of lower case "cr" and upper case "CR" to distinguish between two different levels of review. As bridge engineers, we often perform "cr" as we execute the design. This may include minimizing plate girder flange thickness changes, or it may include weld accessibility for closely spaced bearing stiffeners. "CR," on the other hand, may include where cranes can be placed for girder erection and whether these locations are feasible given the site constraints, or whether the project specifications for lane closure restrictions allow a reasonable window of time for erecting the girders. There is a great benefit to be gained in implementing a constructability review in the QC process.

The QA process must address the interface of disciplines. Typically on a bridge project, there are multiple disciplines working on the project including highway engineers, drainage engineers, utility engineers and traffic engineers. It is imperative that the process include a documented interdisciplinary review to make sure there are no issues with the interface of the different disciplines promoting both consistency and discipline integration. How many times have bridge deck elevations been completed when it is then realized that the bridge engineer does not have the latest roadway profile—or the position of a drainage scupper conflicts with a bridge girder? It is good practice to reduce the risk associated with the interface of disciplines by coupling on-going interdisciplinary coordination with formal interdisciplinary reviews at specified intervals in the project.

Lastly, and all too often once a project is complete, the designers and managers are usually running on to the next project and its looming deadline. However, for proper project close-out, a careful review of the project and documentation of the lessons learned are critical to improving the next project and improving the ability to meet the client's expectations and needs. Documentation of the lessons learned is not enough, though. These lessons must be truly learned by the organization through use and review of them by all of the project teams prior to the start of the next project(s). The QA plan must include this process to promote continuous improvement—an essential part of a comprehensive QMS. ■

This article serves as a preview of Session B22, "Quality and the Bridge Engineer" at NASCC: The Steel Conference, taking place March 26-28 in Toronto. Learn more about the conference at ***www.aisc.org/nascc****.*

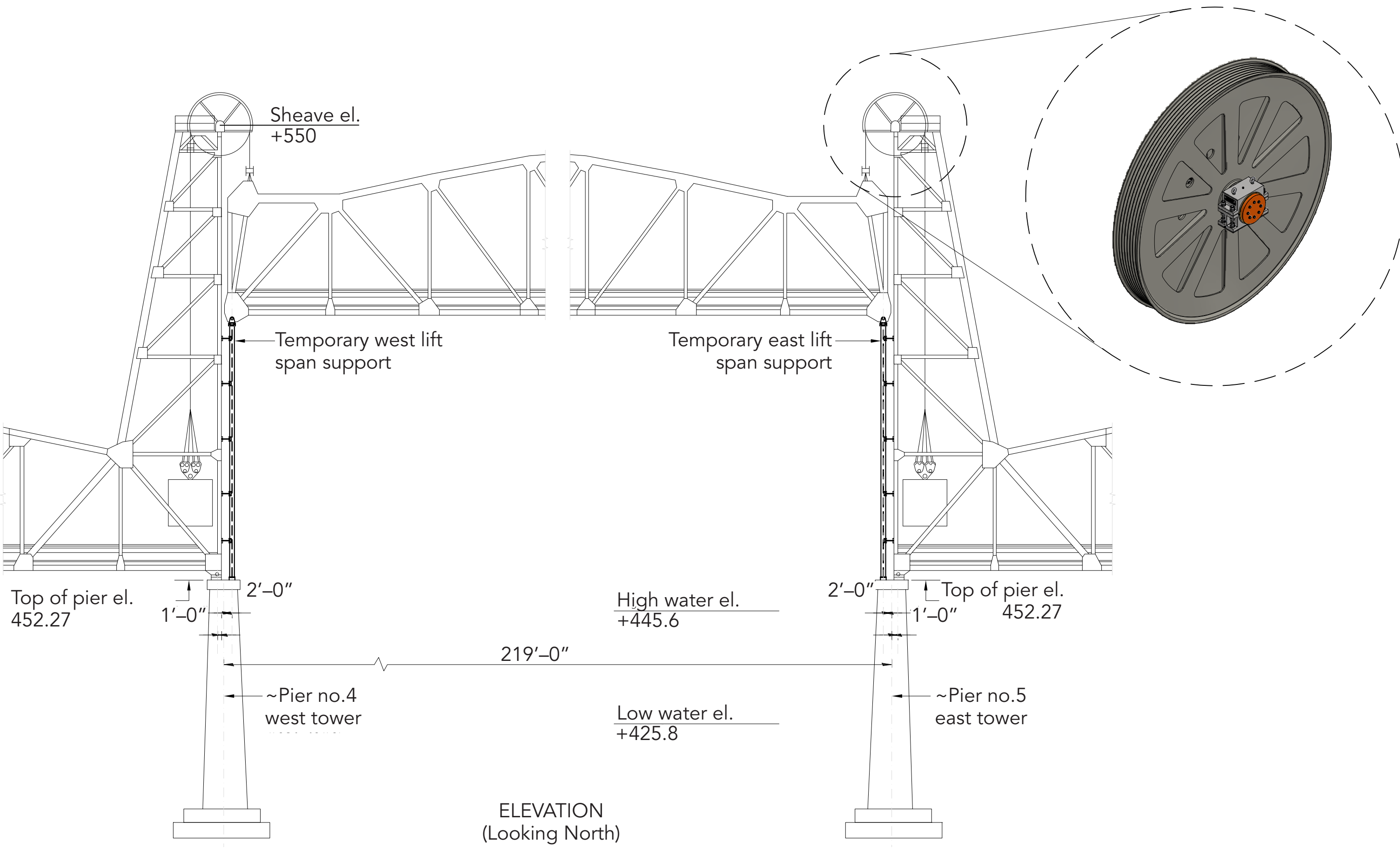
UP & at 'em

A lift bridge rehabilitation project takes place with the lift span in the raised position. And while the bridge was held high, construction time stayed low.

BY JEFF NEWMAN, P.E., AND GEOFF FOREST, P.E.

Jeff Newman (jwnewman@modjeski.com) is director of mechanical engineering for Modjeski and Masters, former Chair of AREMA's C15-SC4 (Movable Bridges) and an active member of HMS (Heavy Movable Structures). **Geoffrey Forest** (glforest@modjeski.com) is a senior mechanical engineer with Modjeski and Masters.

All images: Modjeski and Masters



AS ANY bridge inspector will tell you, it's best to catch small problems before they become big.

In the summer of 2012, a routine inspection of the Florence Bridge, a movable bridge over the Illinois River in Florence, Ill., called for immediate closure of the bridge. The culprit was visible buckling of one of the bridge's main columns that could potentially lead to a partial bridge collapse.

Given the bridge's importance as a major crossing of the Illinois River in the area—it carries Illinois Route 106 over the river—the Illinois Department of Transportation (IDOT) needed to find a solution to bring it back into service as quickly as possible. Fortunately, IDOT had a standing, on-call contract with bridge engineering firm Modjeski and Masters (M&M). The contract allowed IDOT to immediately engage M&M, which was able to quickly mobilize engineers to investigate the damage, develop a response plan and assemble a project team.

Upon closer inspection, M&M confirmed that the damage extended beyond the buckling column. As the column provides support for one of the bridge sheaves, the sheave itself was also shifting laterally, cutting into the trunnion support column. It was feared that continued operation would cause further buckling and could ultimately result in a failure of the whole column and movable span of the bridge.

Staying Open

During the preliminary investigation a definitive cause could not be clearly identified. However, M&M determined that a significant contributing factor for buckling was a mechanical design issue—no longer used in the industry—causing the sheave to move incongruent to its shaft, in turn creating a cork-screw effect.

Over an eight-week period, the M&M team aggressively streamlined the design phase in order to quickly establish a recommendation and contract plans for repairs. A number of the features that were included in M&M's designs ultimately contributed to the rehabilitation of the bridge.

Although the bridge was to remain closed to vehicular traffic, the M&M team recommended that the lift span be supported in an open position, thus allowing barge traffic to continue; ordinarily this type of work would be performed with the lift span sitting in the lowered position. A structural system was designed to support the span in the raised position and involved placing the span on structural "stilts." These stilts were supported at the live load strike plates and extended 55 ft high to support the live load bearings on the lift span. Intermittent anchors attached the stilts to the existing towers for stability. During the active repairs, the stilts carried the full dead load of the lift span.

Today's standards require the designer to provide means and methods for supporting the bridge counterweight in the future for situations such as the one the bridge was experiencing. The Florence Bridge was originally designed and built in 1929, an era when this forethought was not standard practice. As such, the structure had no built-in support to unload the counterweight, and M&M had to analyze and strengthen the structure so that the contractor, Midwest Foundation, could safely and successfully support the counterweight during construction.

With the lift span supported in the fully open position, a jacking system was required to raise the counterweight 20 in. in order to alleviate the weight for the rehabilitation effort. Because of the significant jacking and support effort required, along with other considerations, it was agreed to expand the project's scope and

The lift span was supported in the open position, thus allowing barge traffic to continue during the rehabilitation work.

include replacement of all sheaves and trunnions, counterweight ropes and trunnion bearings. Although the machinery replacement was considered fairly standard for the industry, what made this job unique was the implementation in the field—which, again, took place with the lift span in the raised position to provide a minimum 65 ft of navigation clearance above the Illinois River (high water to low steel).

Realignment

The buckled column and removal of dead load (jacking) caused a loss of the bridge's original alignment. Achieving precise alignment with the installation of the new column was critical for the repair, and M&M required Midwest Foundation to conduct precision surveys, determining existing and final alignments before and after jacking to optimize mechanical functionality.

Installation of the column itself was a complex process that involved hand-cutting the existing column to create an accurate fit. Achieving precise alignment in a shop where the environment is controlled and all work is conducted by machines is one thing. At this bridge site, teams needed to achieve the same precise alignment by hand, working 105 ft above the Illinois River in the dead of winter. Despite the challenges, the new column was aligned within 0.005 in. per ft, relative to the adjacent column, and the repurposed welded sheave with forged trunnion assemblies, each weighing around 10 tons, were aligned using the same precision survey data to at least $^1/_{16}$ in. accuracy or better.

The closure of and repairs to the Florence Bridge were originally met with both public and political resistance, as is to be expected when a bridge is unexpectedly closed (and causes a 40-mile detour). However, as the public began to understand the impact the buckling had on the safety of the bridge, and the extent of the repair being conducted on an accelerated timeline, perception began to shift. The bridge reopened in April 2013 after only ten months of closure—particularly impressive given that projects of this type can typically take up to two years. The expedited timeline was the result of quick response/mobilization, excellent coordination and information sharing with all parties, innovative solutions and spare sheaves available for repurposing—but most importantly the willingness to problem-solve as a team.

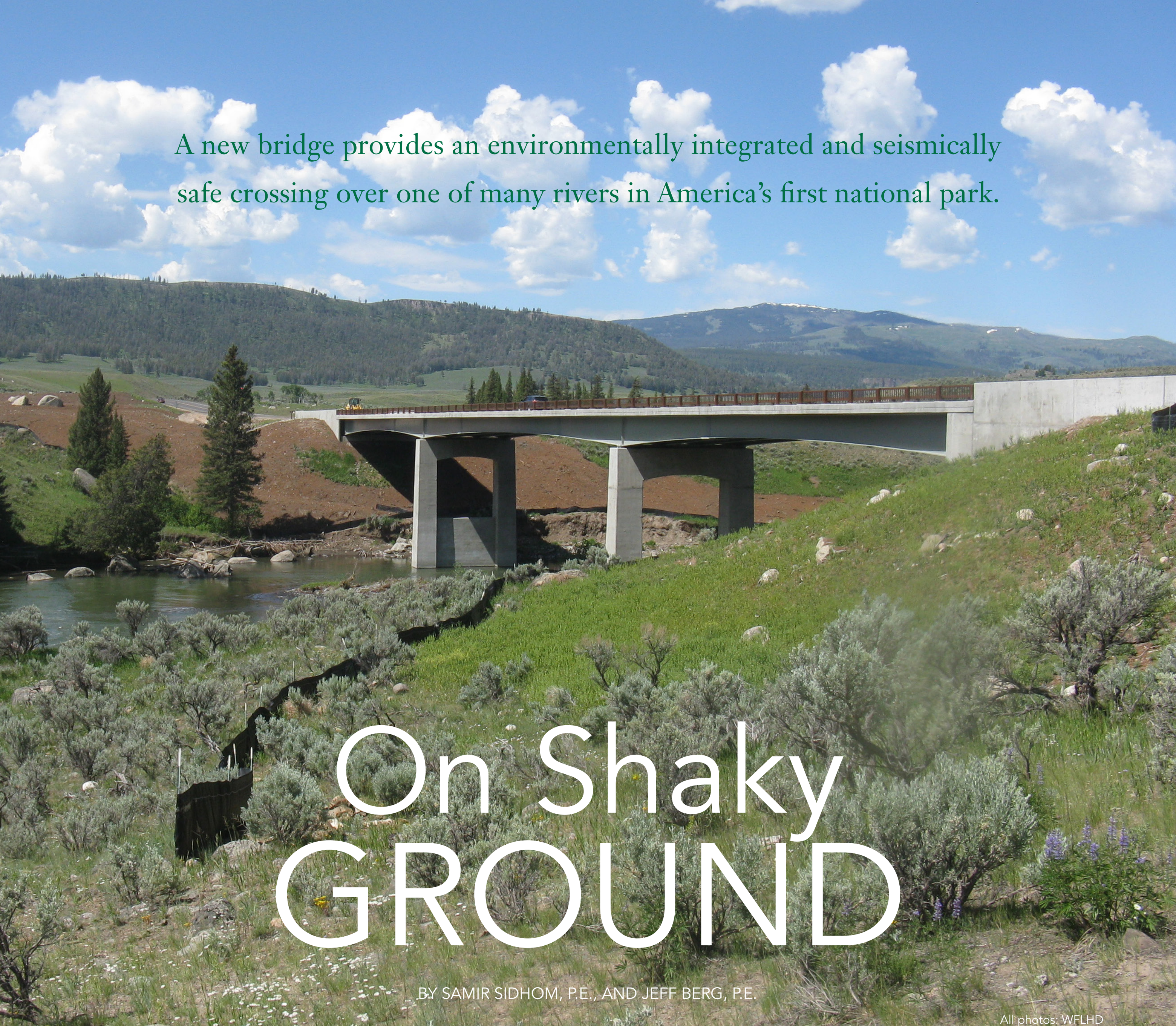
Over the course of the project, M&M worked closely with IDOT to deliver a comprehensive rehabilitation of the entire 1929-built Florence Bridge. If and when another rehab is to happen, there is a plan already in place. ■

Owner
Illinois Department of Transportation

Structural Engineer
Modjeski and Masters

General Contractor
Midwest Foundation Corporation

Steel Fabricator and Detailer
Shawnee Steel and Welding, Inc., Merriam, Kan. (AISC Member/NSBA Member/AISC Certified Fabricator)



A new bridge provides an environmentally integrated and seismically safe crossing over one of many rivers in America's first national park.

On Shaky GROUND

BY SAMIR SIDHOM, P.E., AND JEFF BERG, P.E.

All photos: WFLHD

Samir Sidhom (samir.sidhom@dot.gov)) is a functional team lead with the Central Federal Lands structure group and was the bridge design team leader for the project. **Jeff Berg** (jeff.berg@dot.gov) is a structural engineer with the Western Federal Lands structure group and was a bridge team member on the cross-functional design team for the project.

YELLOWSTONE NATIONAL PARK is home to a variety of wildlife, beautiful landscapes and uncanny geothermal features.

More than 3 million people visit the park every year, and most of them will cross multiple bridges over the park's many water features during their visit. One of these is (or rather was) the Lamar River Bridge, a 335-ft-long, three-span steel structure, built in 1940, that spanned 35 ft to 40 ft above the Lamar River and provided access to the wildlife-rich Lamar Valley and the gateway communities of Silver Gate and Cooke City, Mont.

Due to: severe concrete deck and curb deterioration, which had required the restriction of the permissible loads crossing the structure; the deterioration of the lead-based paint on the steel superstructure; the fracture-critical nature of the girders and floor beam system; and the seismic vulnerability inherent in the 1940 design of the structure, by 2006 it was determined that the bridge was structurally deficient and nearing the end of its service life. In 2007, the Western Federal Lands Highway Division (WFLHD) of the Federal Highway Administration (FHWA), in partnership with Yellowstone National Park, proposed to repair, rehab and/or replace the structure and as such, sought to determine a list of feasible alternatives associated with such work. In February 2008 an engineering study evaluated four courses of action:

1. Rehabilitate the existing bridge and widen the deck.
2. Rehabilitate the existing bridge and replace the entire superstructure.
3. Replace the existing bridge with a new superstructure on the existing alignment.
4. Replace the existing bridge with a new structure on a new alignment immediately adjacent to the existing bridge (a centerline shift).

During the scoping process, Yellowstone solicited public input for any information or suggestions for consideration before developing the environmental assessment plans. In June of 2009, a draft environmental assessment study performed by the Park determined that constructing the new bridge adjacent to the existing bridge would eliminate the need for temporary bridge, offer the most cost-effective, long-term solution to address the deficiencies of the existing bridge and provide for 75+ years of safe, reliable service at this important river crossing.

Setting the middle section of the last girder.

Updated for Tremors

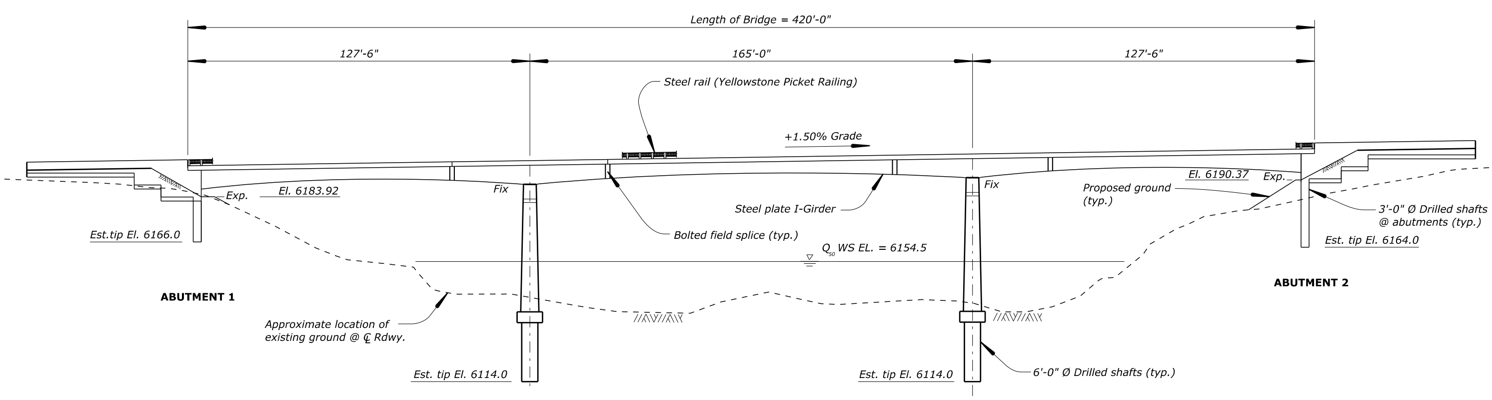
Due to high seismic activity and active faults within 50 miles of the project area (the park sits atop a massive underground volcano) the study assessed the seismic vulnerability of the existing bridge. It revealed that abutments and piers didn't have the adequate reinforcement to withstand a seismic event and that the shallow foundations were subject to rocking during a potential tremor; they were classified as scour-critical, which could eventually undermine the structural integrity of the bridge. The study also found the bridge railings and approach railings didn't meet current AASHTO standards for crash-tested rails.

One of the specific goals of this project was to build a structure with architectural features that matched the overall flavor of the existing structures in the park and surrounding vicinity, in order to blend it into the natural environment. Steel girders have historically been used for bridges in Yellowstone due to their cost-effectiveness and aesthetic lightness, and they were chosen for the new bridge for these reasons too—as well as to match the appearance of the existing bridge.

Following the decision to replace the existing bridge on a new alignment, the WFLHD bridge team developed the preliminary type, size and location (TSL) plans for the new Lamar River Bridge. From there, they asked the Central Federal Lands Bridge Office design team in Lakewood, Colo., to finalize the TSL plans, design and detailing of the project. The plans called for a two-lane, 420-ft-long, 33-ft, 4-in.-wide, three-span (127.5 ft-165 ft-127.5 ft) steel plate girder bridge. It also required four spliced haunched girders supported by two concrete abutments founded on drilled shafts and two concrete piers located within the Lamar River and founded on drilled shafts.

After a preliminary analysis of the superstructure, the Federal Lands Bridge design team finalized the haunched girder dimensions by using 3.75 ft as the minimum depth at the middle of the spans and 6 ft as the maximum depth at abutments and piers. The parabolic shape of the steel girders, with the shallow depth at the middle of the spans, created an aesthetically pleasing and functional structure.

In April 2010, the final bridge package was delivered to WFLHD for incorporation into contract documents. That August, the $7.46 million contract was awarded to Morgen and Oswood Construction Co., Inc. WFL project engineer and inspectors administered the construction contract with the support of the Western Federal Lands bridge team and



ELEVATION

The new Lamar River Bridge is a two-lane, 420-ft-long, 33-ft, 4-in.-wide, three-span (127.5 ft-165 ft-127.5 ft) steel plate girder bridge.

An independent platform was built to carry all construction equipment and materials across the river.

the Central Federal Lands Bridge design team.

Digging Deep

The use of deep foundations in a high-seismic area and the proximity of the project to several faults was, again, one of the challenges faced by the design team. To analyze the effects of the seismic forces on the superstructure, substructure and drilled shafts supporting the bridge piers and abutments, a complete 3D finite element model of the structure was developed. The design team used the latest AASHTO LRFD bridge design specifications to design and detail substructure and foundation elements to meet the seismic requirements of the design code.

Another challenge was the variable width of the column at the bottom of the pier and its connection to the drilled shaft. The column width in the final design was 6.75 ft, which required a minimum 8-ft drilled shaft to reduce the possibility of plastic hinge forming below the bottom of column elevation. The cost of the shafts and transporting equipment capable of drilling them in the river was of major concern. To alleviate these concerns, the design team decided to create a larger footing that connects the base of the column to a 6-ft drilled shaft inside a 1-in.-thick, 14-ft-deep permanent steel casing to reduce the possibility of the plastic hinge forming.

To overcome the challenges of constructing the drilled shafts in an active river and the load restrictions on the existing bridge, the contractor decided to build an independent platform across the river that carried all construction cranes as well as other construction equipment and materials.

Additionally, after finalizing the TSL plan the design team was asked by WFLHD to extend the bridge's flared wing walls at both ends to about 65 ft to match the length of the existing wing walls of the old bridge. The design team decided to separate the wing walls from the structure and design separate wing walls founded on spread footings at the four corners of the bridge. The wing walls were then designed as retaining walls that varied in depth from 12 ft to 4 ft with curtain walls to cover the abutment cap and bearing area. Approach slabs were also provided and connected to the cantilevered end walls at both ends of the bridge. The cantilevered end walls were provided and designed to engage the soil behind the abutments in case of an earthquake. Expansion joints were provided between the end of the approach slabs and the sleeper beams, eliminating any joints along the bridge superstructure.

The new Lamar River Bridge, which uses 270 tons of steel in all, opened to traffic in the fall of 2012; the old Lamar River Bridge was demolished the following June. ■

Owner
Yellowstone National Park

General Contractor
Morgen and Oswood Construction Co., Inc., Great Falls, Mont.

Structural Engineer
Federal Lands Structure Group

Steel Team

Fabricator and Detailer
TrueNorth Steel, Billings, Mont., (AISC Member/NSBA Member/AISC Certified Fabricator)

Erector
Danny's Construction Company, Inc., Shakoppe, Minn., (AISC Member/AISC Advanced Certified Steel Erector)

The alternative technical concept procurement method proves to be the best value for a bridge replacement in Missouri's outdoor vacation paradise.

Alternative APPROACH

BY MARTIN FURRER, S.E., P.E.

THE LAKE of the Ozarks is one of Missouri's most prominent recreation and tourism destinations.

MO Route 5 is a main access road into this region. The route crosses the Osage arm of the lake via the Hurricane Deck Bridge, originally built in 1936 as a 2,200-ft-long steel deck truss structure with 463-ft spans supported on dredged caissons in up to 85 ft of water. In 2009, it was determined that the truss was structurally deficient (due to section loss in the gusset plates) and had reached the end its useful life, and the Missouri Department of Transportation (MoDOT) began making plans to replace it.

The project site presented several challenges, including significant right-of-way restrictions, rock-bluff constraints in the approach roadway and environmental concerns that included nearby Native American burial grounds. On top of that, the closure of the bridge for the duration of the reconstruction was deemed unacceptable by the local stakeholders due to the 42-mile detour.

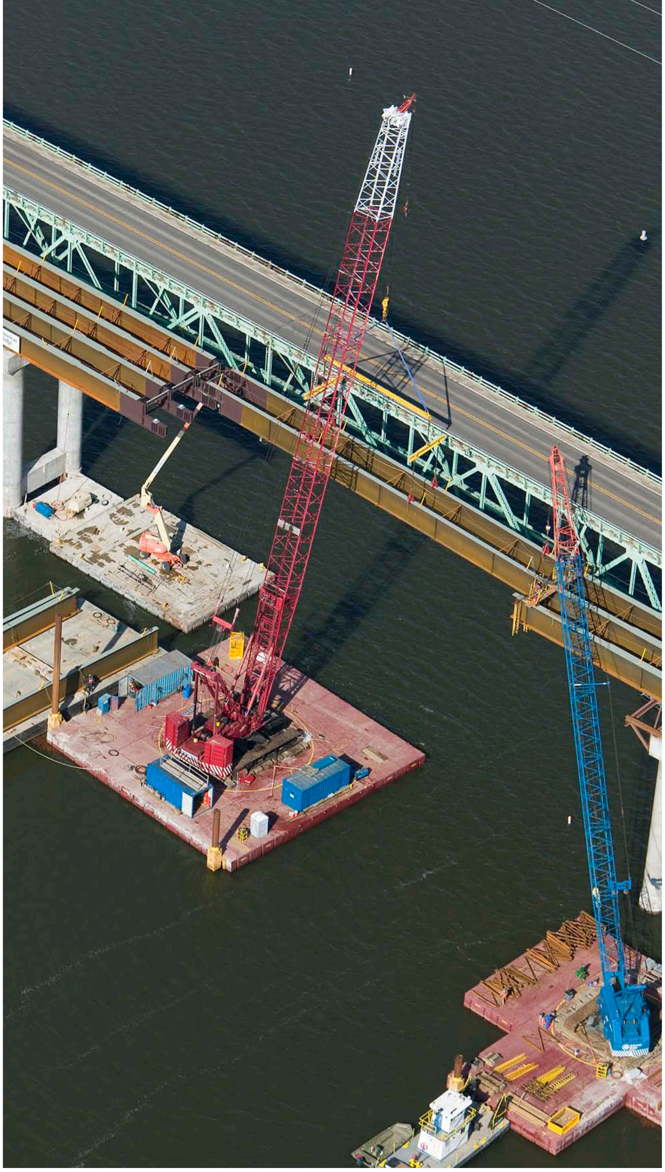
Martin Furrer (martin.furrer@parsons.com) is a senior project manager for Parsons Corporation in Chicago and has been involved in the design and construction of fifteen bridges over major waterways.

Procurement Approach

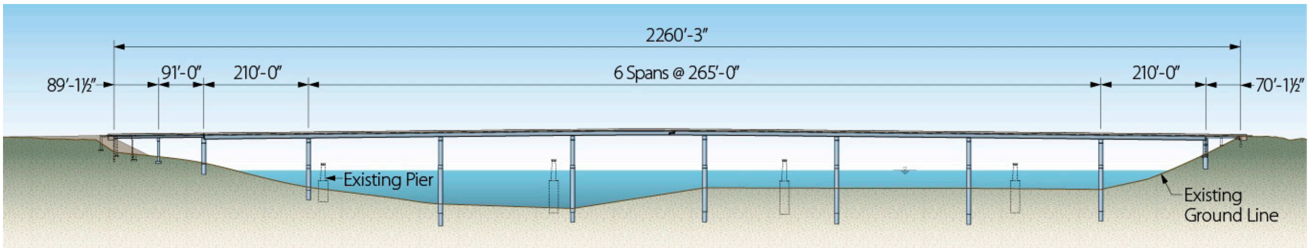
Engineering consultant Parsons was selected to provide the preliminary and final design services for the baseline design concept for the bridge replacement. To encourage contractor innovation, MoDOT elected to employ an alternative technical concept (ATC) procurement method for the project. Under the ATC process, contractors were invited to develop alternatives to, or modifications of, the baseline design with the intent of reducing costs without sacrificing MoDOT's defined project objectives.

Two contractors submitted ATCs that represented significant departures from the baseline concept. The extensive nature of these two ATCs rendered the design cost, schedule duration and required resources prohibitive to performing a complete final design before the bid opening. Considering this limitation, these two contractors collaborated with MoDOT and Parsons to develop a conceptual design focused on defining the variables most crucial to the development of a detailed cost estimate and bid price for the project. Ultimately, these two ATC designs were advanced to only 30% completion before bid submittal, and pre-bid engineering deliverables were minimized. Contractors proposing ATCs that were significantly different from the baseline concept bid the project based on preliminary design quantities developed by Parsons, with quantity growth over 2% being the contractor's risk.

In a nine-month period, Parsons mobilized four teams of designers, including one to perform preliminary design and prepare bid documents for the baseline approach and three to prepare bid packages for the confidential ATCs proposed by the contractors. These design teams were staffed from different offices, and administrative firewalls were designed to ensure



▲ The completed new bridge, open to traffic.
➤ Erecting the girders.
▼ An ATC bridge elevation for the new crossing.



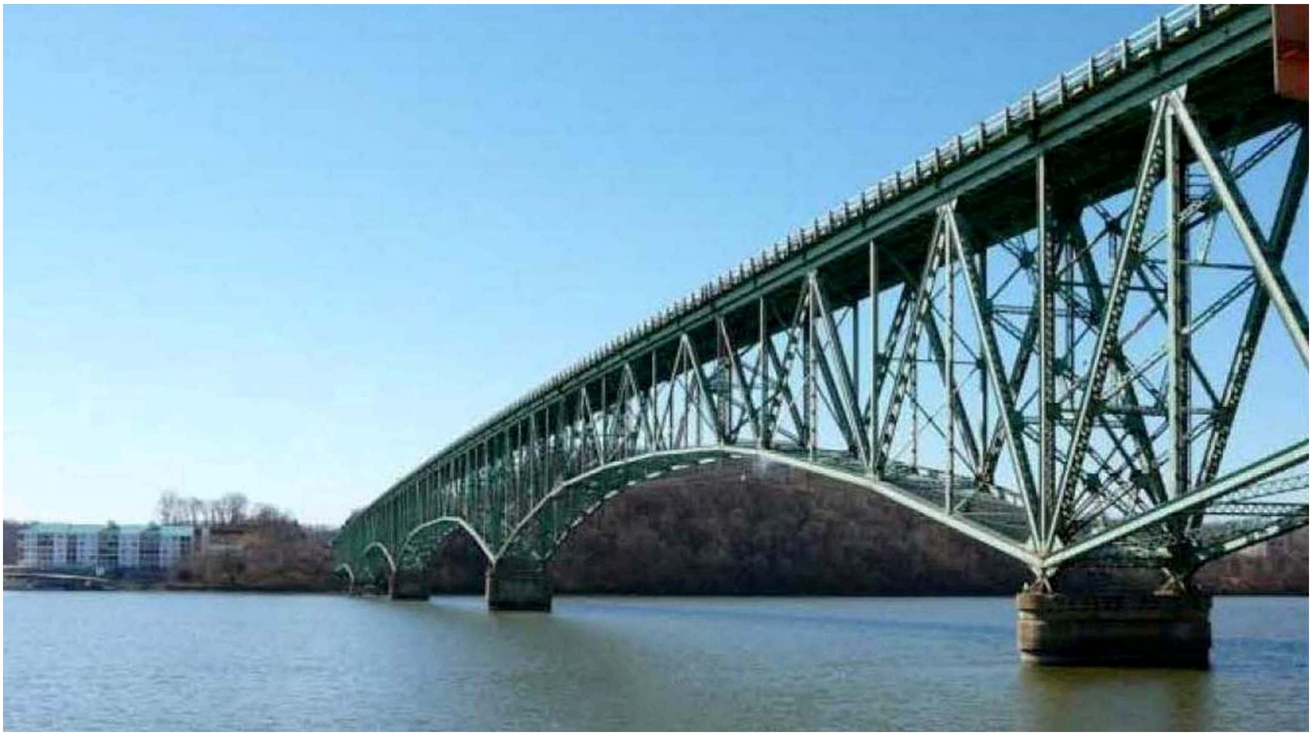
complete confidentiality throughout the bid document preparation process.

Baseline Design

The concept for the baseline design was to reuse the existing caisson foundations by designing a new steel delta frame plate girder structure with matching span lengths. The delta frame structure was to be built immediately adjacent to the existing bridge, supported on 42-in. pipe piles, and tied to the existing foundations. Traffic was to be maintained on the existing bridge while the steel delta frame superstructure was built. Traffic would have then switched to the new bridge on the temporary alignment, and the existing deck truss superstructure and pier caps were then to be demolished. Once the new pier caps were complete, the new superstructure would have been moved laterally onto the rehabilitated permanent piers during a weekend closure.

The triangular-shaped delta frame, extending from the pier cap up to the bridge girders, was proposed for this project due to its ability to support long spans at a significant height with few piers. With the use of the delta frame, original bearing elevations were maintained, thus minimizing any necessary retrofit to the existing substructure.

The delta frame has a typical span of 462 ft, 10 in., matching the existing deck truss spans. Three delta frame girders spaced at 13 ft, 2 in. were used to support the 40-ft, 8-in. roadway cross section, which consists of one 12-ft lane in each direction with 5-ft shoulders and MoDOT Type B Safety Barrier Curbs supported on a 9.5-in. concrete deck cast on stay-in-place steel forms. The delta frame welded plate girders were 130 in. deep and the frame legs had a typical depth of 48 in. All structural steel was designed to be unpainted ASTM A709 Grade 50W weathering steel.



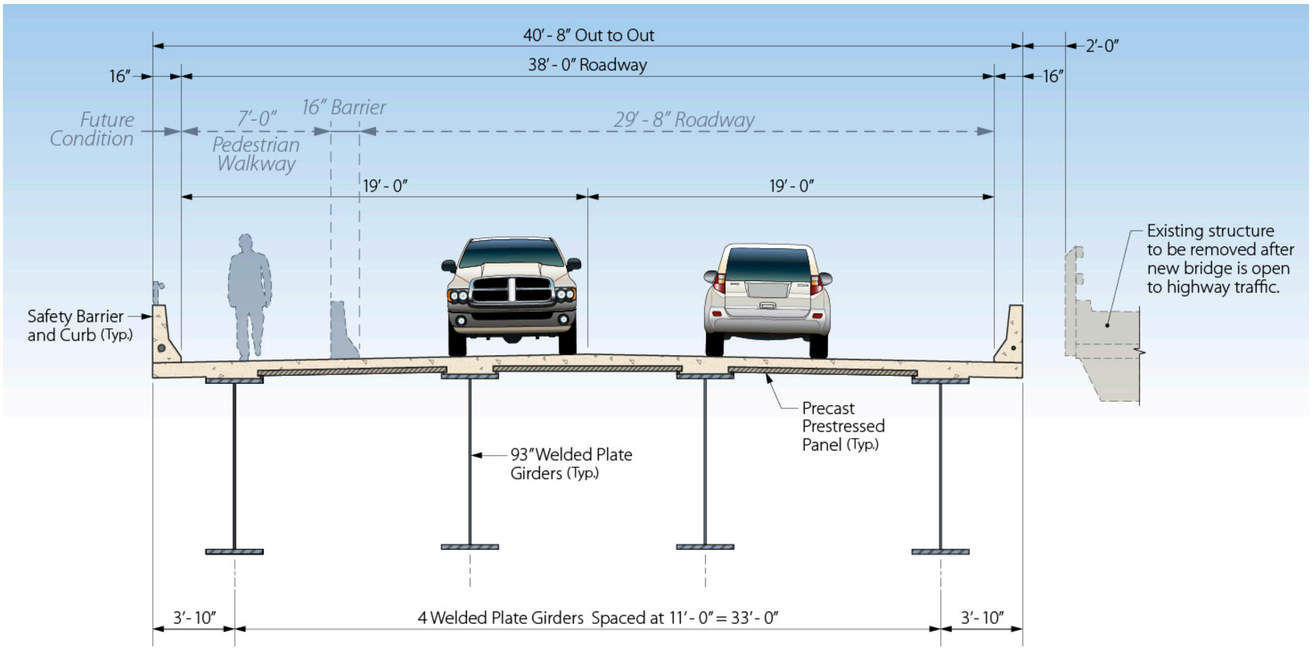
The original Hurricane Deck Bridge.

ATC Design

General Contractor American Bridge Company's ATC involved a total redesign of the baseline concept with a new permanent structure on a new parallel alignment, leaving just 2 ft between the new structure and the old structure. The new structure comprises two plate girder units with six typical spans of 265 ft, 210-ft end spans and an in-span hinge connecting the two units. The steel superstructure is founded on twin 8.5-ft-diameter, steel-cased drilled shafts. An 8-ft barbell strut that sits between the drilled shaft and the 8-ft-diameter column ties the columns together.

The slender substructures are up to 120 ft tall and are braced against sway by the steel superstructure. Instead of proposing a three-girder bridge, as in the baseline design, a four-girder, unpainted ASTM 50W steel bridge with 93-in. web depth was used, reducing deck thickness (8.5 in.), reinforcement, forming and future replacement expenses.

A cross section of the new bridge.



▲ The new structure comprises two plate girder units with six typical spans of 265 ft.

Five contractor bids were received on this project. Two contractors bid the baseline design with no modifications, one elected to bid the baseline design with minor ATCs proposed and two proposed major ATCs to the baseline design. American Bridge's proposed major ATC was the lowest bid, at $32,303,295, closely followed by the contractor that bid the baseline delta frame design with a minor ATC, at $45,765 higher.

The bridge had to be open to traffic no later than the date established in the base design, so the project team had to compress both the design and construction of the ATC into the same schedule allotted by MoDOT for only the construction of the baseline design. This required an accelerated project mobilization. The project was awarded to American Bridge on January 4, 2012, and individual package productions were scheduled carefully so that the release-for-construction drawings were available in time to begin each successive work activity. This integrated design-build-style project management approach facilitated successful design and construction in less than the time provided for only the construction of the baseline bid.

Demolition on the existing bridge began this past December and was expected to be completed in March, at the time of publication. The new bridge, which uses approximately 2,100 tons of structural steel, opened to traffic on September 9, 2013, three months ahead of schedule. ■

This project was featured in Session B6 at the World Steel Bridge Symposium in Toronto in March. Go to ***www.aisc.org/nascc*** *to view the presentation.*

Owner
Missouri Department of Transportation

General Contractor
American Bridge Company, Midwest District, Overland Park, Kan.

Structural Engineer
Parsons Corporation, Chicago and St. Louis offices

Steel Team

Fabricator
W&W/AFCO Steel, Little Rock, Ark. (AISC Member/NSBA Member/AISC Certified Fabricator)

Detailer
ABS Structural Corporation, Melbourne, Fla. (AISC Member)

An innovative steel truss strategy delivers a bi-state vertical lift bridge in just 18 months.

A New Way to CONNECT

BY THEODORE P. ZOLI, P.E., AND STEVE DELGROSSO, P.E.

Trey Cambern

THE WORLD WAR I Memorial Bridge has been bringing two states together for nearly a century.

Built in 1923, the bridge was a steel stitch across the Piscataqua River that pulled together the towns of Portsmouth, N.H., and Kittery, Maine. Carrying up to 20,000 vehicles a day, it allowed both communities and states to benefit economically and socially from resources on the opposite bank. In recent years, though, it had to be closed due to structural deterioration.

"We tried to keep it functioning as long as we could," said Keith Cota, chief project manager for the New Hampshire Department of Transportation, which shared ownership of the bridge with the Maine Department of Transportation. "We closed it in phases, first to vehicular traffic then eventually to pedestrian and bicycle traffic."

Repairs were made to keep the bridge operational for river traffic while the owners began the process to procure a replacement. To speed up delivery, the bi-state agencies chose design-build procurement and issued a request for proposals. Understanding the hardship and economic impact caused by the bridge's closure, the design-build team of HNTB Corp. and Archer Western Contractors pledged to deliver an innovative vertical lift steel bridge in 19 months—five months faster than other bids that were made. The team was awarded the $90 million project, the largest highway and bridge contract in the history of the New Hampshire Department of Transportation and the state's first design-build job.

The design uses 2,375 tons of 50-ksi steel and features three identical 300-ft through truss spans, a 163-ft lift tower on each of the two flanking spans, two 11-ft through lanes, two 5-ft shoulders for bicyclists, two 6-ft sidewalks inside the truss planes (which eliminate the need for special bridge inspection equipment) and a pedestrian overlook at both flanking spans.

"The proposed structure had to be similar in mass and size to the original bridge so it would not detract from its historic setting," Cota said. "It fits nicely in this location."

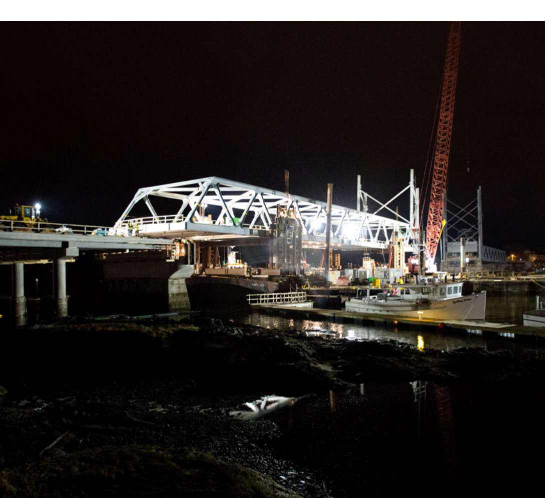
Weighing 1,250 tons, the center span of the truss bridge raises to provide 150 ft of clearance during high tide. It is balanced by counterweights of 625 tons each.

The bridge uses 2,375 tons of steel.

Ready for traffic.

The center span can raise to provide 150 ft of clearance.

Night work.



As the bridge raises and the ropes slacken, two sets of gigantic chains, typically used for ships' anchor lines, engage as a counterbalance. L-shaped mini cranes on each tower allow operators to add or remove steel plates over the life of the structure to maintain an accurate balance between counterweight and lift spans.

Positioning the mechanical system below deck, a first for vertical lift bridges, helps to create a streamlined appearance and cleaner operations, since elements that require routine maintenance and greasing are below deck. Having the auxiliary drive on one end of the main span and the primary drive system on the other end, connected by a longitudinal cross shaft in the plane of the bottom chord, results in machine rooms that are readily accessible for inspection and maintenance activities without inconvenience to pedestrians or vehicular traffic. A key to this arrangement is that all of the mechanical equipment could be preassembled and the entire machine room hoisted and attached to the bottom chord of the truss, speeding up lift truss assembly.

Facilitating Efficiency and Speed

To bring the bridge together quickly and efficiently revolved around what the design didn't include rather than what it did. For starters, gusset plate connections weren't part of the design. Gusseted truss connections are especially susceptible to deicing salts, which are prevalent in the Northeast. These connections act as pockets where snow, salt and debris collect, causing corrosion and damage to the structural steel. These connections are not only difficult to access for inspection and maintenance but are also nearly impossible to replace without traffic closure and the use of temporary falsework.

The solution was simple: Create a design that eliminates the troublesome connections and instead fabricate the top and bottom chords of the wide-flange sections in much the same way plate girders are fabricated; this offers an immense savings in time. With plate girder-type fabrication, there is little or no penalty for increasing the depth of the bottom chord. The bottom chord acts as a beam in strong axis bending and offers the possibility for true truss redundancy, where the loss of a diagonal can be effectively redistributed in chord bending. Instead of a truss chord depth of 14 in. to 18 in., typical for 30-foot spans, the final design uses 36-in. I-section bottom chord.

With the truss' gusset connections gone, diagonals are connected to the chords via a conventional spliced connection. Rather than the connection being at the node, where the diagonals meet the top and bottom chords, the design moved the splice away from the bottom chord and up the diagonals to enhance fabrication, as well as ease maintenance and inspection.

Splicing the diagonals allowed each flange and the webs to connect to independent plates. This, in turn, permitted piece-by-piece replacement—a significant cost-saving and life-extending advantage over conventional gusset plate design. This configuration also pre-compresses the joint in a highly efficient way. The plates are compact and the bolts are tightly spaced, which helps prevent rust buildup. Overall, the truss design makes the bridge significantly more resistant to corrosion and less costly to maintain.

Designing a deeper bottom chord meant the stringers could be eliminated by using intermediate floorbeams that subject the bottom chord to bending and tension. Thus, the deck system spans longitudinally between floor beams, making the superstructure system easier to fabricate, erect, inspect and maintain.

Bolts were also minimized. Flanges and webs are connected using two sandwich plates, subjecting the bolts to double-shear. Having double-shear connections at every node reduces the number of bolts to half that of a traditional gusset plate connection, saving time and labor costs in both fabrication and installation. Although this truss design uses up

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The design features two 11-ft through lanes, two 5-ft shoulders for bicyclists, two 6-ft sidewalks and overlooks at both flanking spans.

to 30% more structural steel, the savings in time and labor costs from minimizing the bolts made it extremely cost-competitive with conventional trusses.

While the design strategy for the truss was innovative, in order to reduce risk it had to incorporate as much repetition or uniformity as possible. To speed up fabrication, each of the three spans has identical geometry, with the only variable being exterior flange size (i.e., top flange of the top chord and bottom flange of the bottom chord). All other geometry—webs, interior flanges and diagonals—remained the same.

When it came to coatings, the cost of shop-applied metalizing was about the same as the specified four-coat paint system, but it provided the added benefits of schedule acceleration and life-cycle cost savings. Further, design specifications called for 1/8 in. of sacrificial steel, meaning the trusses had to withstand a certain amount of corrosion without their performance being meaningfully impacted.

For the framing and truss systems, the team used a minimum of 1-in.-wide heavy plates. The heavy metal design yielded a truss bridge that is stronger, safer, more resistant to corrosion and more resilient to potential vessel collisions. Using the same weight in all spans made construction easier as well.

"Metalizing and heavy plates ensure the bridge will easily exceed the required 75-year design life with a 100-year expectancy being much more realistic," Cota said.

Testing Mettle

On paper, the design appeared to accelerate delivery, but its true mettle would be tested during fabrication. Steel fabricator Structal Bridges brought the design to life in its Claremont, N.H., plant. Work orders included the steel bridge superstructure, both 163-ft towers and the three through truss spans.

"Fabrication was the key to achieving the aggressive schedule," Cota said. "This is the first truss bridge to have been built with cold-bent steel flanges. Structal had to develop new weld strategies for the truss chords, particularly for the flange-to-web connections, which incorporate the curved flanges."

Most of the fabrication challenges were resolved on the first truss span. Learning curves on the second and third truss spans were much shorter, which underscored the purpose of the repetitive design.

After the spans were fabricated, Archer Western assembled each one on a barge and floated it out to the construction site. The three floats were timed to coincide with the Piscataqua River's high tide. All three spans were constructed by April 2013 and in place by June 2013. Facing a $25,000-a-day incentive/disincentive, Archer Western crews sometimes worked 20-hour shifts seven days a week to deliver the bridge on time and give the community back its mobility. In the end, the design proved its mettle both in fabrication and construction.

"People come into my office, see the renderings of the proposed bridge and think it is a picture of the actual bridge," laughed Cota. "That's how much the renderings mirror what was built."

"Residents are in love with the bridge," he said. "It immediately resumed its place as the heartbeat of the community." ■

Owners
New Hampshire Department of Transportation
Maine Department of Transportation

General Contractor
Archer Western Contractors

Structural Engineer
HNTB Corporation
HDR, Inc. (Structural Consultant)

Steel Team

Fabricator
Structal Bridges - A Division of Canam Steel Corporation, Claremont, N.H. (AISC Member/NSBA Member/AISC Certified Fabricator)

Detailer
Tenca Steel Detailing, Quebec City, Quebec, Canada (AISC Member)

NSBA

2014 Prize Bridge AWARDS

FIFTEEN BRIDGES HAVE EARNED national recognition in the 2014 Prize Bridge Awards Competition. Conducted by the National Steel Bridge Alliance (NSBA), the program honors outstanding and innovative steel bridges constructed in the U.S.

The awards are presented in several categories: major span, long span, medium span, short span, movable span, reconstructed, special purpose, accelerated bridge construction and sustainability. This year's winners range from a reconstructed bridge that had been partially destroyed by a barge to a massive delta frame spanning the Shenandoah River.

Winning bridge projects were selected based on innovation, aesthetics and design and engineering solutions, by a jury of five bridge professionals:

- Benjamin Beerman, Senior Structural Engineer, Federal Highway Administration/Resource Center, Atlanta
- Thomas R. Cooper, P.E., P.Eng., Lead Structural Engineer, Parsons Brinckeroff, Denver
- Robert Healy, Director of Structures, RK&K, Baltimore
- Thomas P. Macioce, P.E., Division Chief of the Bridge Design and Technology Division, Pennsylvania Department of Transportation, Harrisburg, Pa.
- Bert Parker, Senior Vice President/Chief Administrative Officer, Garver, Little Rock, Ark.

This year's competition attracted more than 30 entries and included a variety of bridge structure types and construction methods. All structures were required to have opened to traffic between May 1, 2011 and September 30, 2013.

The competition originated in 1928, with the Sixth Street Bridge in Pittsburgh taking first place, and over the years more than 300 bridges have won in a variety of categories. Between 1928 and 1977, the Prize Bridge Competition was held annually, and since then has been held every other year, with the winners being announced at NSBA's World Steel Bridge Symposium.

2014 PRIZE BRIDGE AWARD WINNERS

Prize Bridge Award winners

- Major Span: Shenandoah River Bridge Delta Frame, Jefferson County, W.Va.
- Medium Span: Dixie Highway Flyover, Boca Raton and Deerfield Beach, Fla.
- Moveable Span: Willis Avenue Bridge, New York
- Reconstructed: Huey P. Long Bridge, New Orleans
- Special Purpose: Phyllis J. Tilley Memorial Pedestrian Bridge, Fort Worth, Texas

Merit Award winners

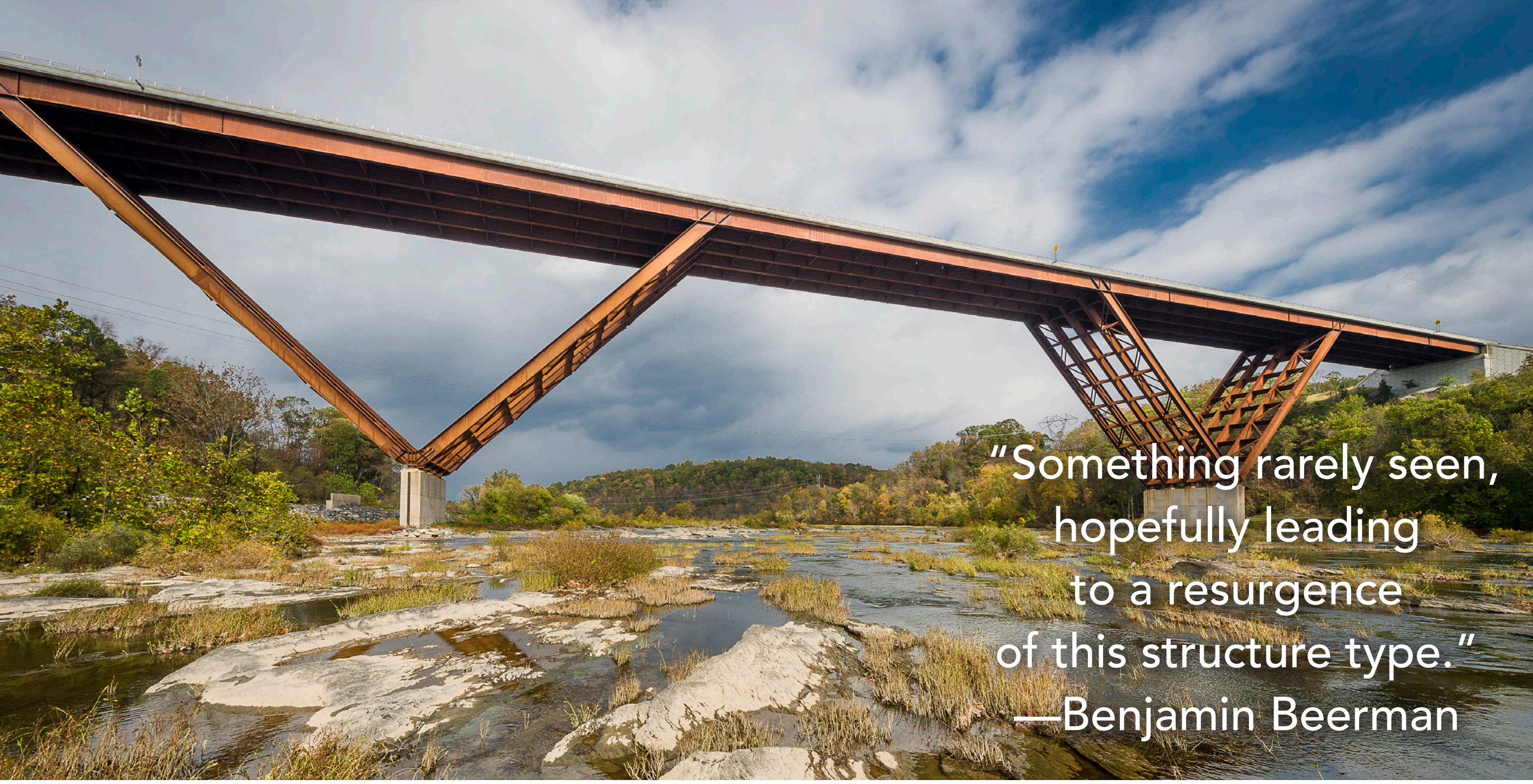
- Major Span: Sakonnet River Bridge, Tiverton and Portsmouth, R.I.
- Long Span: Iowa Falls Bridge, Iowa Falls, Iowa
- Medium Span: North Halsted Street Tied Arch Bridge, Chicago
- Medium Span: Ramp TE over I-95, New York
- Short Span: River Road Over Ironstone Brook, Uxbridge, Mass.
- Short Span: Dodge Creek Bridge, Elkton-Sutherlin Highway (OR138), Ore.
- Reconstructed: Eggner's Ferry Bridge Emergency Replacement, Trigg and Marshall Counties, Ky.
- Special Purpose: Christina and John Markey Memorial Pedestrian Bridge, Revere, Mass.

Accelerated Bridge Construction Commendations

- Willis Avenue Bridge, New York
- River Road Over Ironstone Brook, Uxbridge, Mass.
- 130th Street and Torrence Avenue Railroad Truss Bridge, Chicago
- Eggner's Ferry Bridge Emergency Replacement, Trigg and Marshall Counties, Ky.

Sustainability Commendations

- Dodge Creek Bridge, Elkton-Sutherlin Highway (OR138), Ore.
- Huey P. Long Bridge, New Orleans
- Keene Road Bridge, Richland, Wash.



PRIZE BRIDGE AWARD—
Major Span Category

SHENANDOAH RIVER BRIDGE DELTA FRAME, JEFFERSON COUNTY, W.VA.

The opening verse to John Denver's "Take Me Home, Country Roads" hints at the natural beauty of the Shenandoah River Valley in West Virginia's eastern panhandle.

To accommodate increasing travel demands to the area, which is about an hour from Washington, D.C., the West Virginia Division of Highways initiated a project to improve West Virginia Highway 9, including a new bridge across the Shenandoah River. HDR developed a delta frame design that delivered significant savings compared to proposals for more traditional designs. The resulting signature shape of the Shenandoah River Bridge is as pleasing to the bottom line as it is to the eye.

The triangular shape of the delta frame, one of the most basic structural forms, yields a sense of stability and strength, of simplicity and functionality. The earth-tone reddish-brown color of the weathering steel blends with the natural colors of the valley and is bounded and complemented by the natural concrete color of the deck and barriers, as well as the piers and abutments.

HDR and Trumbull performed preliminary design on both concrete and steel options, but the anticipated construction

PRIZE BRIDGE AWARD—Medium Span Category

DIXIE HIGHWAY FLYOVER, BOCA RATON AND DEERFIELD BEACH, FLA.

The Dixie Highway is done doubling up. The last remaining two-lane stretch, in northern Broward and Palm Beach Counties (Fla.), has been expanded to four lanes in the form of a flyover that crosses the Florida East Coast (FEC) Railroad, several local streets and the Hillsboro Canal, a waterway that separates the cities of Boca Raton and Deerfield Beach.

Two separate structures were constructed using a total of 3,250 tons of structural steel. The main bridge is a 1,390-ft, eight-span, S-curved, steel box girder bridge with a super-elevation transition. The steel tubs are 6 ft and 7 ft deep for ease of maintenance and sit 16 ft to 30 ft above grade. The second bridge is a single-span, 218-ft single steel box pedestrian bridge connecting Pioneer Park in Deerfield Beach to Boca Raton over the canal.

Design challenges included integral pier cap girders at each column and the large number of vertical and horizontal clearances and transitions between the main bridge and ramps. Waterway width was also a challenge; while Hillsboro Canal is technically a navigable waterway, it is not wide enough to accommodate construction barges. The long box tub girder spans were lifted into place by two 250-ton crawler cranes working in tandem. It was the first time a 192.5-ton steel cap, the single largest component, was ever lifted over and permanently set above the FEC Railroad, which continued to operate freight trains through the construction site every half-hour on weekdays. As construction activities needed to be coordinated with the railroad's train schedule, most heavy lifts took place on weekends and overnight hours.

With only seven months allotted for design and release to construction, the fast-track design-build project finished 95 days ahead of schedule and $7.5 million under budget. The bridge officially opened in July 2012 and was funded through a $40 million American Recovery and Reinvestment Act grant. The completed project, including associated roadway, drainage, signalization and drainage improvements, eliminates an existing at-grade crossing of the FEC Railroad, reduces travel times for local businesses and residents and provides a more efficient hurricane evacuation route for the area. Now, all motorists, pedestrians, and bicyclists can travel safely and efficiently between Boca Raton and Deerfield Beach.

Owner
Florida Department of Transportation, District Four, Fort Lauderdale, Fla.

Engineer
Kimley-Horn and Associates, Inc, West Palm Beach, Fla.

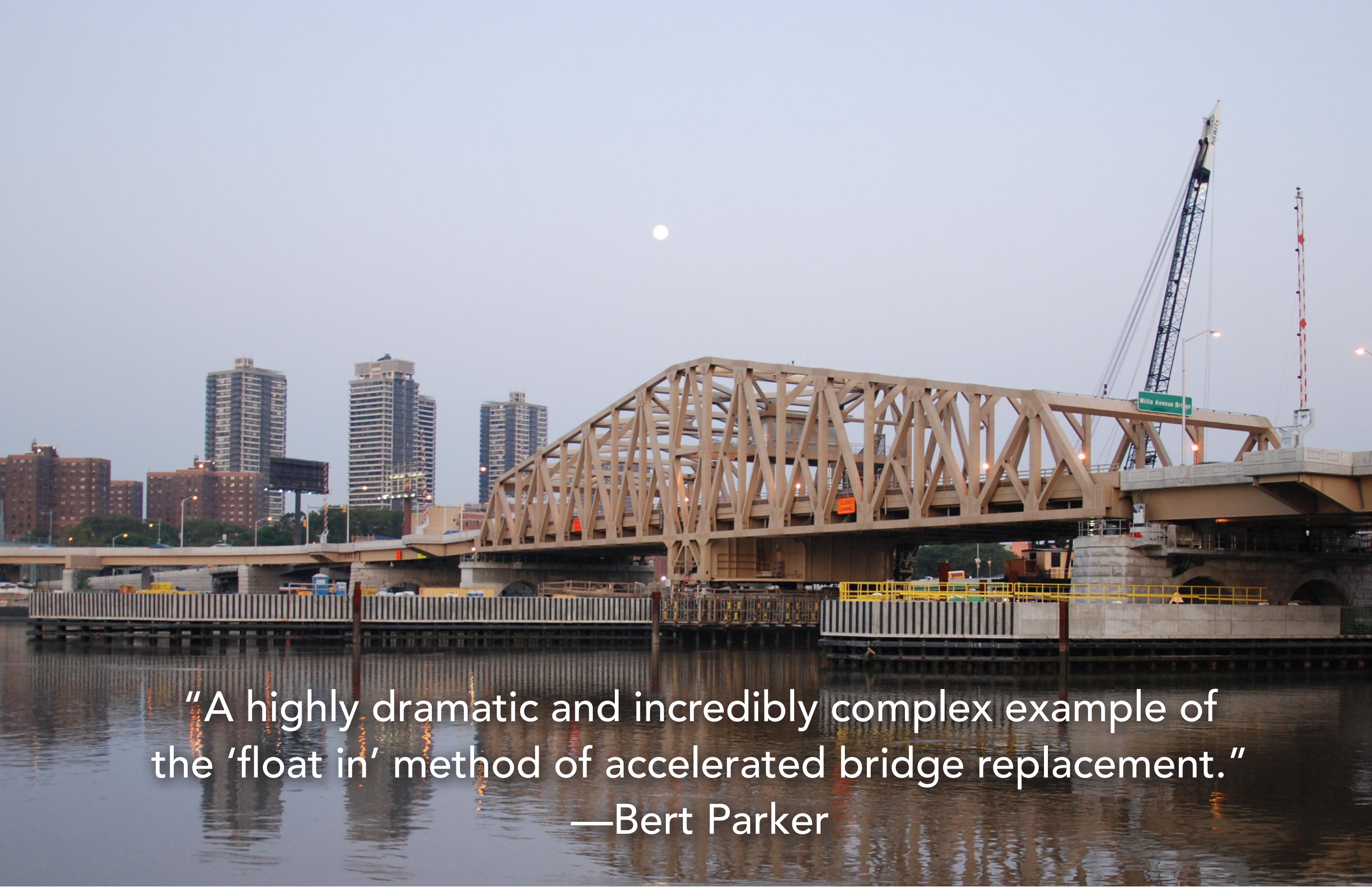
General Contractor
Cone & Graham, Inc., West Palm Beach, Fla.

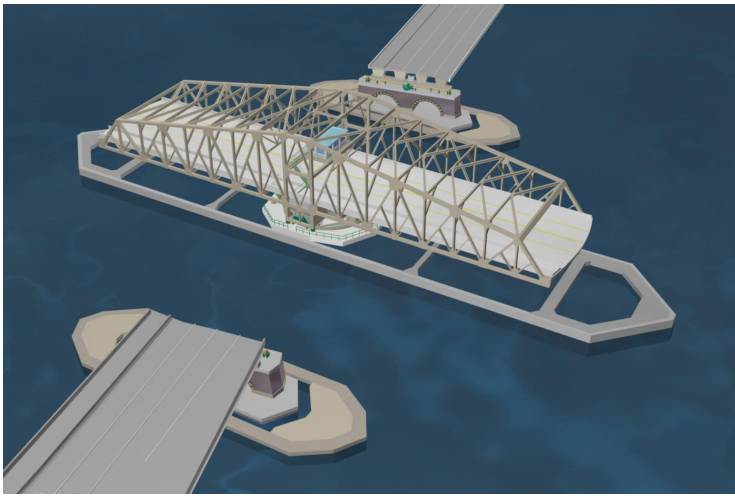
Steel Team

Fabricator
Tampa Steel Erecting Company, Tampa, Fla. (AISC Member/NSBA Member/AISC Certified Fabricator)

Erector
V&M Erectors, Inc., Pembroke Pines, Fla. (AISC Member/AISC Certified Erector)

Detailer
Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member/NSBA Member)





PRIZE BRIDGE AWARD—Movable Span
ACCELERATED BRIDGE CONSTRUCTION COMMENDATION—Movable Span Category

WILLIS AVENUE BRIDGE, NEW YORK

The Willis Avenue Bridge brings boroughs together. The bridge is integral to connecting Manhattan and the Bronx, carrying roughly 72,000 vehicles per day via four lanes of traffic across the Harlem River. It also provides an important pedestrian and bicycle corridor—and is on the route of the New York City Marathon.

The 25-ft vertical clearance of the 350-ft-long swing span portion allows most vessels in the river to pass below, but the span swings open periodically to permit the passage of tall vessels. Although the swing span is the centerpiece of this bridge, this is just a short segment of the three-quarter-mile-long structure. Elevated ramp connections are provided from First Avenue at E. 125th Street and from the Northbound FDR Drive in Manhattan to Willis Avenue and to Bruckner Boulevard in the Bronx.

Due to structural deterioration and alignment issues, the bridge needed to be replaced. The new swing span is a steel through truss and the approach spans include trapezoidal box girders and straight and curved plate girders as well as transverse box girders straddling Harlem River Drive and the at-grade section of Willis Avenue below the bridge. A total of roughly 8,000 tons of structural steel were incorporated in the final project. A separate curved girder ramp, designed by a consultant for New York State DOT, provides a direct connection to the Major Deegan Expressway.

The 2,500-ton swing span portion was preassembled and floated into position on-site. This highly publicized operation included the spectacle of the bridge floating down the Hudson River roughly 160 miles from the assembly site near Albany, including a tour around the tip of Manhattan and below the city's East River bridges. Floating the swing span in allowed simplified erection on land and rapid site installation, minimizing impacts on navigation and vehicular traffic.

A 9-ft-diameter spherical roller thrust bearing supports the entire swing span while minimizing friction during span operation and providing needed seismic restraint. This is the largest application of this type in the world for a spherical roller thrust bearing. Swing span machinery, electrical and maintenance areas were integrated with floor system framing below deck level to simplify future maintenance access and integrate the mechanical and structural components in a way that provided direct load paths from the balance wheels and center wedges to the main structural members.

The truss arrangement offers a modern design solution that is consistent with other historic swing spans on the river and provides a defined gateway to the Bronx. The clean closed box truss members are detailed to minimize future maintenance needs, while features such as architectural fences and pier treatments are used to enhance the appearance of this significant bridge.

The project produced a range of social and economic benefits including essentially eliminating traffic impact during construction, improving highway safety and operations and providing a continuous, mile-long, 12-ft-wide bikeway/walkway on the bridge that interconnects the bike routes at both ends.

Owner
New York City Department of Transportation, New York

Engineer
Hardesty & Hanover, New York

General Contractor
Kiewit Constructors, Inc./Weeks Marine Inc., a Joint Venture

Steel Detailer
Tenca Steel Detailing, Quebec, Canada (AISC Member)

"A span-by-span method of steel truss assembly and erection allowed the bridge to be widened without falsework in the river."
—Tom Macioce

PRIZE BRIDGE AWARD & SUSTAINABILITY COMMENDATION—Reconstructed Category

HUEY P. LONG BRIDGE, NEW ORLEANS

At the grand opening of the Huey P. Long Bridge Widening Project last June, Louisiana Secretary of Transportation and Development Sherri H. LeBas hailed the event as "the rebirth of a great bridge, which symbolizes the continued rebirth of this great city."

Originally completed in 1935, the bridge was built to carry both rail and highway traffic. At 23,000 ft between railroad abutments, the main spans of the bridge included two 18-ft highway travel lanes cantilevered off of the railroad bridge.

After a study conducted determined that a new crossing was not a viable option, the Louisiana Department of Transportation and Development in 1986 began investigating widening the existing span. Modjeski and Masters, the structural firm that designed the original Huey P. Long Bridge, was also engaged to design the expansion.

The final approved design involved expanding lanes from two 9-ft lanes to three 11-ft lanes, with a 2-ft inside shoulder and an 8-ft outside shoulder. As an expansion of this magnitude was unprecedented, design teams faced the additional challenge of executing an extensive analysis of the new main bridge superstructure, as well as the original bridge.

Construction for the massive project began in April 2006. The seven-year schedule was broken into four phases of construction, including:

- Phase I: Main Support Widening (piers) – Began April 2006, completed end of May 2009. Prime contractor: Massman Construction Co.
- Phase II: Railroad Modifications – Began October 2006, completed June 2008. Prime Contractor: Boh Bros. Construction Co.
- Phase III: Main Bridge Widening (truss) – Began early 2008 completed July 2012. Contractor: MTI, a joint venture of Massman Construction Co., Traylor Brothers, Inc. and IHI, Inc.
- Phase IV: New Approaches Construction – Began June 2008 and concluded August 2013. Contractor: KMTC, a joint venture of Kiewit, Massman Construction Co., and Traylor Brothers, Inc.

During the first phase, river piers were widened from 60 ft to 80 ft by encasing the lower portion of existing piers with concrete. The encasements supported a new steel "W" frame that was in turn used to support the widening trusses. The 53-ft-tall steel frame is 152 ft wide at the top but only 75 ft wide at its bearings. Once the steel W frame was supported, teams could widen the main river spans.

You can read more about this project in "The Long Way Home" (12/2012).

Owner

New Orleans Public Belt Road Railroad, New Orleans

Louisiana Dept. of Transportation & Development, Baton Rouge, La.

Program Managers

Louisiana Timed Managers, Baton Rouge

Engineer

Modjeski and Masters, Inc., New Orleans

General Contractor

MTI, a joint venture of Massman Construction Co., Traylor Brothers Inc., and IHI Inc.

Massman Construction Company

KMTC, a joint venture of Kiewit, Massman Construction Co., and Traylor Brothers, Inc.

Boh Brothers Construction

Steel Team

Fabricators

W&W/AFCO Steel, Little Rock, Ark. (AISC Member/NSBA Member/AISC Certified Fabricator)

American Bridge Manufacturing, Reedsport, Ore. (AISC Member/NSBA Member/AISC Certified Fabricator)

Industrial Steel Construction, Gary, Ind. (AISC Member/NSBA Member/AISC Certified Fabricator)

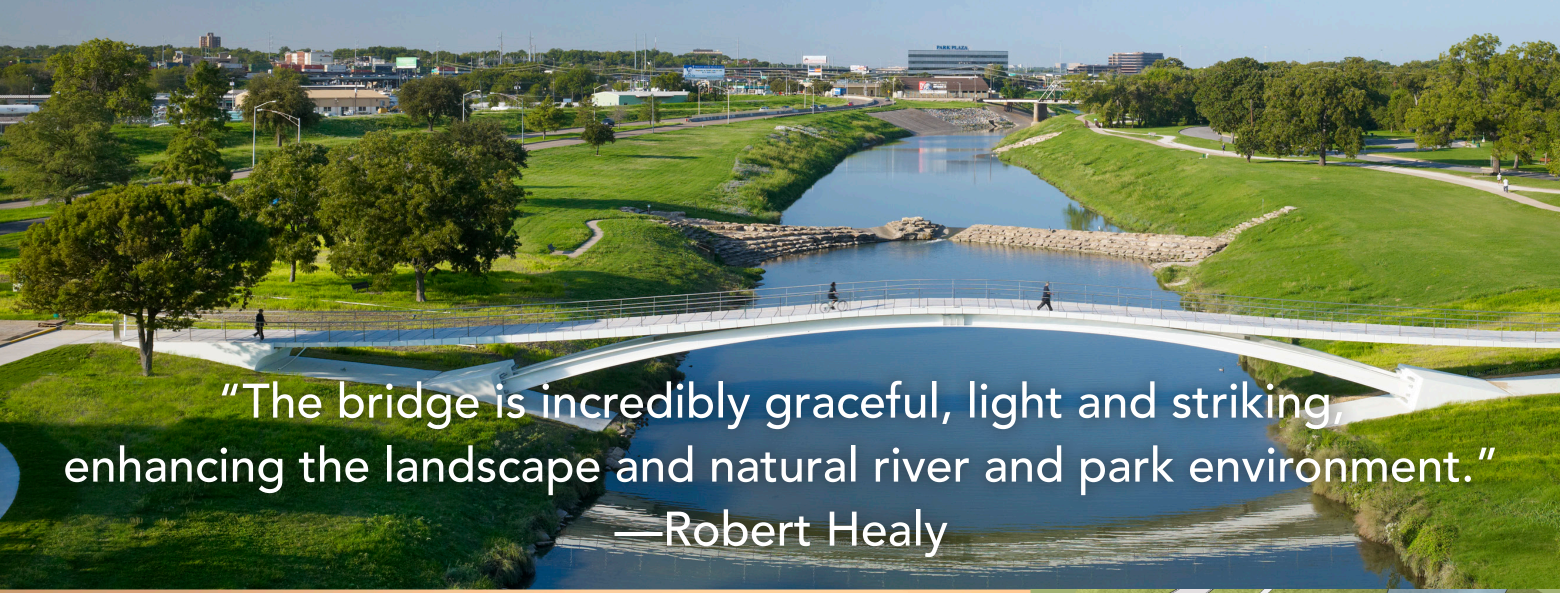
Cosmec Inc., Athens, Texas (AISC Member/NSBA Member AISC Certified Fabricator)

Steel Detailers

Candraft Detailing Inc., New Westminster, B.C., Canada (AISC Member)

Genifab Detailing and Engineering for Fabricators, Quebec, Canada (AISC Member)

Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member/NSBA Member)



> "The bridge is incredibly graceful, light and striking, enhancing the landscape and natural river and park environment."
> —Robert Healy

PRIZE BRIDGE AWARD—Special Purpose Category

PHYLLIS J. TILLEY MEMORIAL PEDESTRIAN BRIDGE, FORT WORTH, TEXAS

Residents of Ft. Worth now have an elegant new path over the Trinity River. Connecting Trinity Park to a new trail that terminates in downtown Fort Worth, the new Phyllis J. Tilley Memorial Bridge has a graceful profile that enhances the serene landscape. A steel arch with a span of 163 ft supports steel stress ribbon segments and precast concrete planks over the river, complementing the adjacent historic Lancaster vehicular bridge.

The 368-ft-long, 12-ft-wide steel stressed ribbon/arch combination bridge is named for Phyllis Tilley, an advocate for use of the riverfront. Pedestrians and bicyclists crossing the bridge will experience a smooth, undulating ADA-compliant bridge surface. At night, the bridge is illuminated with a combination of white and blue LED lighting for increased safety and aesthetic appeal. The absence of vertical arch support struts reduces the horizontal loads created by periodic river flooding. The bridge's slim profile belies the strength and versatility of the design, which enables the structure to sustain a 500-year flood event without raising flood elevations more than one inch.

One important challenge with stress ribbon bridges is achieving a deck running slope that meets ADA accessibility requirements and maximum allowable slopes. Since a stress ribbon bridge is in fact a catenary structure that derives its strength from the sag of the supporting ribbon, the deck slope must follow the sag of the ribbon, and this slope can easily exceed ADA limits. To meet this challenge, the precast concrete deck panels were designed with varying thicknesses to provide a finished deck surface with a series of short ramps and landings that meet ADA requirements.

This bridge represents a cooperative funding effort by the City of Fort Worth, federal agencies and private donations through Streams and Valleys, Inc., a local not-for-profit organization that helps to protect and enhance the Trinity River and its adjacent trails. These groups invested a total of $2.5 million for a bridge that has already had a significantly positive impact on the local area since its dedication in August 2012. The bridge is the first pedestrian crossing of the Clear Fork of the river in the last 20 years.

Owner
City of Fort Worth, Texas

Engineer of Record
Freese and Nichols, Inc., Fort Worth

Structural Bridge Engineer
Schlaich Bergermann and Partner, LP, New York

Architect
Rosales + Partners, Boston, Mass.

General Contractor
Rebcon, Inc., Dallas

MERIT AWARD—Major Span Category

SAKONNET RIVER BRIDGE, TIVERTON AND PORTSMOUTH, R.I.

The Sakonnet River Bridge carries R.I. Highway 24 over the Sakonnet River, a tidal passage separating the Town of Portsmouth on Aquidneck Island to the west and the Town of Tiverton on the mainland to the east.

Located just to the south of where the Sakonnet River opens into Mount Hope Bay, the Sakonnet River Bridge setting is one of mixed use, comprised of established neighborhoods with 19th and early 20th century homes, pleasure boat marinas, fishing wharves and commercial real estate.

The replacement structure accommodates two 12-ft lanes in each direction, 4-ft-wide high-speed shoulders, 10-ft-wide low-speed shoulders and a 13-ft-wide bicycle/pedestrian shared-use path on the north side of the bridge; this path introduces a pedestrian and bicycle connection between the two towns that has been absent for more than half a century.

After studying bridge types for the replacement structure, it was decided that the most reasonable and prudent decision would be to design and advertise two separate structure types. These types included 1) an unpainted weathering steel trapezoidal box girder structure and 2) a twin segmental concrete trapezoidal box structure. Extensive architectural enhancements were included to "dress up" these economic structure types.

The final design has ten girder spans ranging from 100 ft to 400 ft. Several enhancements, including a boat ramp and handicap accessible fishing pier, were included in the contract. The project was advertised in October of 2008 and bidding opened the following January. The low bid was about $165 million for the steel alternative design, which was then constructed. Due to overlapping areas with the existing bridge, the new bridge was built in phases in order to maintain traffic at all times, and four full lanes of traffic were operational on the new structure in September of 2012.

Ultimately, this bridge is noteworthy for its cost-effective structure type, which is tastefully enhanced with architectural and lighting features. In addition, innovative pile details allowed for combined side-friction and end-bearing in difficult soils, thereby minimizing driving depths. An incentive/disincentive program helped to fast-track the construction schedule, rendering the existing bridge out-of-service as soon as possible and lifting the heavy truck restrictions of this highway route. An automated electronic vibration and displacement instrumentation and alert system was attached to the existing bridge, and several of the existing piers were pre-outfitted for emergency jacking.

Owner
Rhode Island Department of Transportation, Providence, R.I.

Engineer
Commonwealth Engineers & Consultants, Inc., Providence, R.I.

General Contractor
Cardi Corporation, Warwick, R.I.

Steel Team

Fabricator
Hirschfeld Industries - Bridge, Colfax, N.C. (AISC Member/NSBA Member/AISC Certified Fabricator)

Detailer
abs Structural Corporation, Melbourne, Fla. (AISC Member/NSBA Member)

MERIT AWARD—Long Span Category

IOWA FALLS BRIDGE, IOWA FALLS, IA

The site of the Iowa Falls Bridge in Iowa Falls, Iowa, has seen a lot of action over the last century.

The recently built bridge replaced a 1928 concrete arch bridge that had undergone seven rehabilitation efforts, including major ones in 1976 and 2000. Eventually, the original structure of the concrete span was found to be structurally deficient, functionally obsolete and too costly to rehabilitate again. Although the structure was on the National Register of Historic Places, the Iowa DOT opted to demolish it and replace it with a modern steel bridge on the same alignment.

The arch rib used on this structure used a nearly square cross section rather than a rectangular configuration common with traditional arch ribs. Consequently, the web plates near the base of the arch are thicker than normal. Conventional design practices use wind bracing between the arch ribs to minimize lateral bending forces in the arch rib as a result of wind loads perpendicular to the arch rib. However, due to the width-to-span ratio, a trussed bracing system was deemed inefficient and impractical. Instead, four struts were provided between the arch ribs to allow them to share the lateral loads, which required designing the arch ribs and struts for biaxial bending plus compression.

Redundancy was designed into the hanger cables and tiebacks at the abutment. In case of damage to the hanger cables, the cables were designed to accommodate full roadway traffic with any one of the four cables in a set removed or damaged. The tiebacks at the abutments are encased in HSS and grouted to add additional protection to withstand small impacts, such as those associated with light excavation equipment that might be used if the buried utilities off the end of the bridge had to be accessed. Also, by using lightweight backfill, the abutment was designed so the failure of one tie will not result in a progressive failure of the remaining ties in the abutment.

As part of its bridge infrastructure program, the Iowa DOT focuses on investigating the use of new high-performance materials, new design concepts and construction methods, and new maintenance methods. These progressive efforts are intended to increase the life span of bridges while also making them safer and more cost-effective. By increasing the longevity of the Iowa Falls Bridge and thus minimizing traffic disruption, the public will experience fewer construction-related travel delays moving forward.

To achieve the greatest service life on the Iowa Falls Bridge, a number of corrosion-resisting systems were incorporated into the design. The structural steel is A709 Grade 50 weathering steel. Areas exposed to road-salt spray and runoff are painted with a three-coat paint system to further protect the structure. The inside of the arch rib is also prime-coated for its entire length. The sockets, pins and threaded rods connecting the hanger cables to the arch rib and interior floor beams are galvanized. The cables have a Class A zinc coating on their interior strands and a Class C zinc coating on the exterior strands for additional corrosion protection.

The Iowa DOT testing and monitoring program, developed in coordination with the Iowa State University Bridge Engineering Center, collects performance data for structures to compare against design-based structural parameters and to determine if the structural response is appropriate. Its most challenging research program has been related to developing structural health monitoring (SHM) to determine the real-time and continuous structural conditions of a bridge. For the Iowa Falls Bridge, the goal was to implement a multi-sensor continuous SHM system for general performance evaluation (structural, environmental, etc.) that can easily be adapted to other highway and interstate bridges and other monitoring needs. The system allows easy access to real-time data the Iowa DOT can react to immediately. To this end, a SHM system was developed by the BEC and placed on the bridge. Sensors monitor wind speed, potential icing conditions, traffic, heavy loads, corrosion, moisture, strain on the arch and cables and other conditions to help evaluate the performance of the structure, its materials and its long-term safety.

Owner
Iowa Department of Transportation, Ames, Iowa

Engineer of Record
HDR Engineering, Inc., Omaha, Neb.

General Contractor
Cramer and Associates, Grimes, Iowa

MERIT AWARD—Medium Span Category

NORTH HALSTED STREET TIED ARCH BRIDGE, CHICAGO, IL

Just a few years ago, the Halsted Street Bridge over the Chicago River North Branch Canal put in its 100th year of service.

Built in 1908, the movable double-leaf trunnion bascule truss bridge provided navigable waterway accessibility for vessels too tall to pass beneath when it was closed. Due to the cost of maintaining a movable bridge and the lack of high-mast vessels using the canal, the movable mechanisms of the bridge were decommissioned over 25 years ago and the movable spans were locked together in the closed position.

More recently, the bridge became identified as the only remaining bottleneck to Halsted Street traffic and had become structurally obsolete (in 2007, it earned a sufficiency rating of 25.9 out of 100), and the Chicago Department of Transportation (CDOT) retained structural engineer Lochner to design a replacement.

The new replacement structure consists of a 157-ft-long, 80-ft-wide steel tied arch bridge main span flanked by two 36-ft three-sided precast concrete arch approach spans. With the new bridge deck 22-ft wider than the existing bridge, the replacement bridge carries two lanes each of northbound and southbound vehicular traffic, with one bike lane and pedestrian sidewalk placed on each side. Architectural enhancements were incorporated into the project, including architectural lighting and railings. The pleasantly wide sidewalks of the bridge are shielded from the vehicle traffic by cables and railings. This design arrangement provides the motorists as well as pedestrians with a much safer traffic environment.

To accommodate the roadway with four vehicular lanes and two bike lanes, the arch ribs are spaced at 60 ft. center-to-center; the rib element is a 2-ft, 6-in-wide by 3-ft-deep welded steel box. For simplicity, the rib is braced with a lateral system that consists of only four top struts rigidly framed with the ribs. The interior of the tie girder is painted bright white for the convenience of future inspection via cameras through the hand holes.

The major force carrying cambered members also include arch ribs, ties and cable hangers. For the tied arch bridge, which is designed as a rigid moment frame in nature, member cambering not only serves to achieve a desired final bridge geometry, but also helps to reduce the member forces by injecting a counteracting force into the structural system through erection. Similar to the "prestressing" concept used for the concrete structure, introduction of the counteracting torsional moments imposed on the steel structural system allow the design to minimize the structural size and maximize the efficiency of the steel usage. Although the savings of the structural steel to the project was a direct benefit, additional indirect benefits included the use of lighter false work and reduction in demand for the crane capacity.

The original bridge was closed after Thanksgiving Day of 2010, and on Christmas Eve of 2011 the main construction of the project was complete and Halsted Street Bridge was open to vehicular and pedestrian traffic on schedule. The total final construction cost, including approach spans and roadway construction, was $13.7 million, well under the allocated city budget for the project.

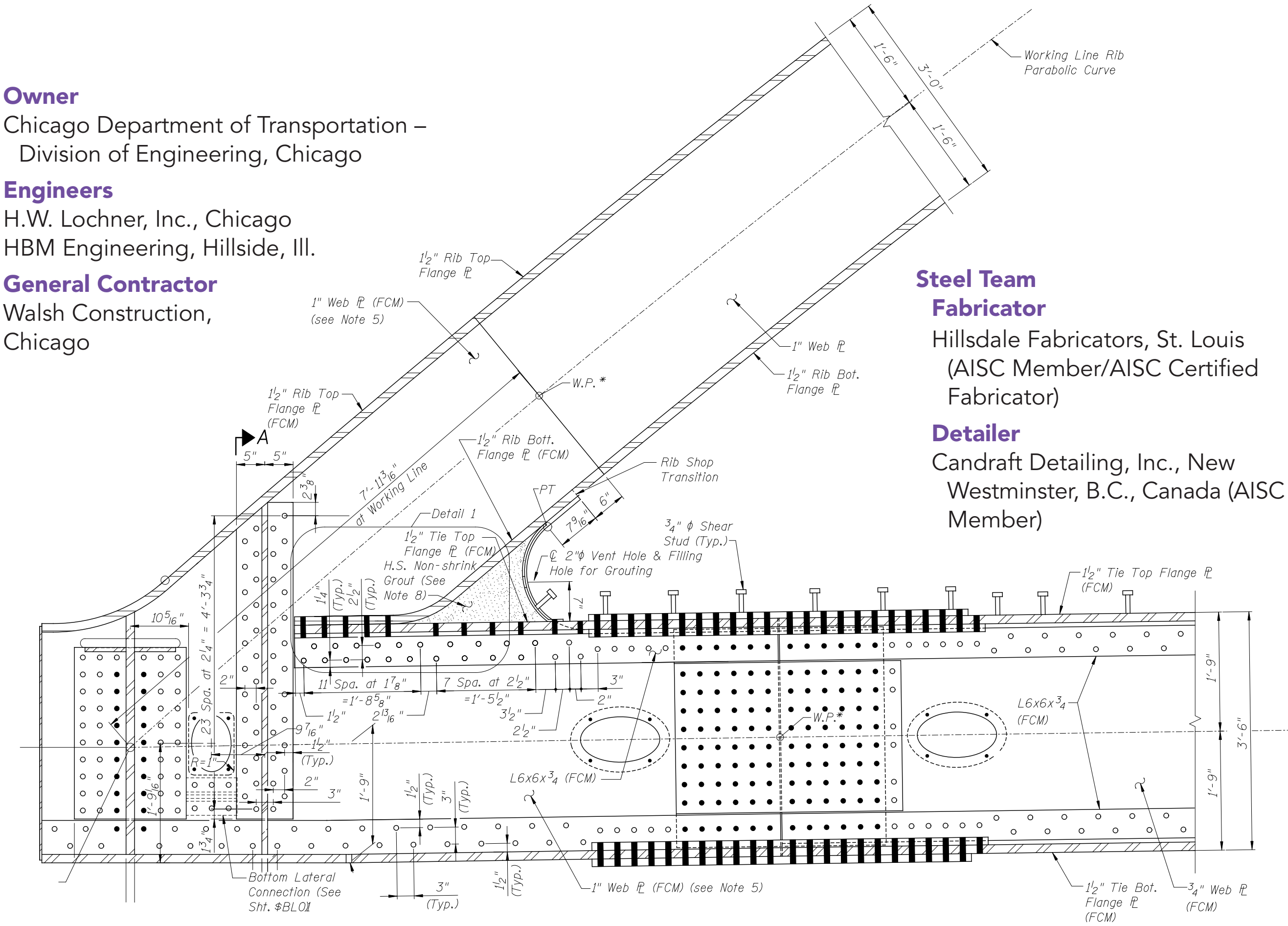
The tied arch bridge is a valid design option for enhancing an urban setting with an aesthetically pleasing structure. The successfully completed project demonstrates that a short-span tied arch can be done economically with attention to the steel details that accommodate both accessibility and constructability. Plus, its size speaks to its adaptability and usefulness in tight quarters, and it validates that site issues can be overcome by thoughtful design.

For more on this project, see "Chicago Crossing" (06/2013).

Owner
Chicago Department of Transportation – Division of Engineering, Chicago

Engineers
H.W. Lochner, Inc., Chicago
HBM Engineering, Hillside, Ill.

General Contractor
Walsh Construction, Chicago



Steel Team

Fabricator
Hillsdale Fabricators, St. Louis (AISC Member/AISC Certified Fabricator)

Detailer
Candraft Detailing, Inc., New Westminster, B.C., Canada (AISC Member)

MERIT AWARD—Medium Span

RAMP TE OVER I-95, NEW YORK

The Ramp TE bridge replacement covers a lot of ground (or at least spans over it).

The project is part of the rehabilitation of the Alexander Hamilton Bridge complex on I-95, the Cross Bronx Expressway (CBE) between Amsterdam Avenue in New York County and Undercliff Avenue in Bronx County. The bridge supports the tightly curved Ramp TE over the West Approach spans of the main I-95 bridge.

The existing Ramp TE bridge was a 660-ft-long concrete box girder design with 10 simple spans and a center line radius of 210 ft. The bridge was located totally within a New York City park and had an existing pier located in the median of the CBE, in the center of the west approach spans of the Alexander Hamilton Bridge.

The reconstruction of the Alexander Hamilton Bridge required a widening to each side of the Mainline Bridge of 11 ft. In order to provide the necessary lateral clearances to permit this widening, two of the piers of the Ramp TE bridge structure needed to be relocated as they were positioned immediately adjacent to the edge of the roadway deck of the main bridge. Furthermore, one of the piers supporting Ramp TE was located in the center median of the CBE, in the middle of Span 2W of the Alexander Hamilton Bridge, and effectively prohibited the relocation of traffic lanes during staged construction for the mainline bridge on the west side of the Harlem River.

It was decided to replace the bridge structure in its entirety, with a design that eliminated the pier in the central median of the CBE. The new bridge structure for Ramp TE is a twin steel tub girder structure supporting a reinforced concrete composite deck. It was built in the same location as the existing bridge and remains on a very tight centerline radius of 210 ft with a 6% super elevation. The number of spans was reduced from 10 equal spans of 66 ft to a five-span arrangement of varying centerline lengths, with the piers positioned to suit the existing features. The abutments were retained, as were two pier shafts and foundations; new cap beams were constructed for these shafts. The other two piers have foundations that used existing spread footings but have complete new shafts.

The design of the new bridge structure was controlled fully by the extremely tight radius of the center line. The client had specified that the top flanges of the box girders be provided with permanent horizontal bracing as a forward-looking measure in the event that a re-decking project would be required at some point in the future. The controlling condition for the design of the top flange bracing was the placement of the deck concrete, due to the unbalanced torsional effects resulting from the concrete placement operation. As such, the sequence for placing the concrete deck sections was rigorously defined in the contract plans.

A further item of interest was that it had been agreed that the structure would be fully continuous throughout its length. This decision arose primarily from the fact that the original bridge had two expansion joints located adjacent to existing piers 4 and 7. These expansion joints had deteriorated severely and it was decided that if possible there would be no interior expansion joints in the new structure throughout its length. As a result, the expansion arrangement of the bridge assumes that the bridge is fixed at new pier 2 and will expand in a guided fashion at all other piers and abutments.

Owner
New York State Department of Transportation, Long Island City, N.Y.

Engineer
Jacobs, New York

General Contractor
Halmar International/CCA Civil, Nanuet, N.Y.

Steel Fabricator
Structal-Bridges, Claremont, N.H. (AISC Member/NSBA Member/AISC Certified Fabricator)

MERIT AWARD—Short Span
SUSTAINABILITY COMMENDATION

DODGE CREEK BRIDGE, ELKTON-SOUTHERLIN HIGHWAY, ORE.

One of the Oregon Department of Transportation's (ODOT) chief concerns is the increasing need for rehabilitation on the state's older bridges.

And a chief concern in bridge design and construction is the need for spans that are cost-effective and are environmental friendly—which is where superior materials like weathering steel come in. Weathering steel performs well in parts of Oregon that meet the requirements of the Federal Highway Administration Technical Advisory T5140. However, the state of Oregon was curious about steel types that could reduce steel bridge lifecycle costs in the coastal portion of the State. High-performance steel (HPS) is an important step in increasing toughness and provides a slight increase to the corrosion index compared to weathering steel. However, HPS may still be vulnerable in corrosive and high humidity environments or coastal climates.

One conventional way to provide corrosion protection of bridge steels is to apply protective paint coatings and periodically recoat the bridge during its service life. But the life-cycle cost of this design choice can be much higher than the initial cost of the bridge. An alternative to weathering steel, HPS and painted steel girders is corrosion-resistant ASTM A1010 Grade 50 steel that needs no corrosion protection coating and has better toughness that supersedes toughness properties of Grade HPS 50W. ASTM A1010 is a low-cost stainless steel with 10.5-12%Cr that can perform for 125 years in coastal environment without a need to maintain for corrosion.

Based on encouraging research and development results, ODOT went ahead with a trial project to design and fabricate of the first public ASTM A1010 steel plate girder bridge in the nation, and ArcelorMittal USA agreed to provide the steel plate. The bridge, with a total length of 132 ft, 6 in. and a width of 42 ft, 8 in., uses just over 80 tons of structural steel. FHWA supported ODOT's proposal by awarding an Innovative Bridge Research and Deployment grant to cover the extra cost for design and fabrication of the first steel plate girders bridge for public use using ASTM A1010 corrosion-resistant steel in the nation.

Owner and Engineer
Oregon Department of Transportation, Salem

General Contractor
Concrete Enterprises, Inc., Salem

Steel Team

Fabricator
Fought & Company, Tigard, Ore. (AISC Member/NSBA Member/AISC Certified Fabricator)

Detailer
Carlson Detailing Service, Fort Worth, Texas (AISC Member)

MERIT AWARD—Short Span
ACCELERATED BRIDGE CONSTRUCTION COMMENDATION

RIVER ROAD OVER IRONSTONE BROOK, UXBRIDGE, MASS.

The Massachusetts Department of Transportation (MassDOT) is a leader in the use of Accelerated Bridge Construction (ABC) practices.

So when it decided to replace a small bridge carrying River Road over Ironstone Brook in the Town of Uxbridge, Worcester County, with a folded steel plate girder structure, ABC guided the project.

The first application of its kind, the folded steel plate girders were fabricated from a single steel plate of uniform thickness that was then bent along multiple lines using a hydraulic metal press break to form an inverted tub shaped section. A system applicable for spans up to 60 ft in length, this type of fabrication eliminates costly details and processes that have made steel alternatives less competitive than other materials for short span bridges. The need for welding is significantly reduced, and the stability of the resulting girder shape eliminates the need for both internal and external cross framing.

To accelerate construction, the design used four 50-ft-long, 24-in.-deep folded steel plate girders, each pre-fabricated with a 6.5-in.-deep, 4-ksi concrete deck section attached using ¾-in.-diameter end welded shear studs. Each beam utilized a single 0.5-in.-thick, 50-ksi steel plate measuring 50 ft in length and 106 in. in width. These dimensions were critical to ensure that the multiple bends could be made using a standard press break. After bending them to the required shape, a minimal number of welded components were then attached to the beams, including end plates, sole plates and headed shear studs. Four bolted flange separator plates were also attached to the bottom of each girder to help maintain shape, and the entire beam was galvanized.

The decks were then cast in a precast shop with the beams oriented in an upright position with falsework supporting the cantilevers. The shipping width of each interior superstructure module measured 10 ft, 2 in. including headed rebars protruding 11 in. from each edge of the precast slab. Each exterior module was 8 ft, 7 in. in width including a single edge of protruding rebar and an integral concrete curb cast along the exterior slab edge.

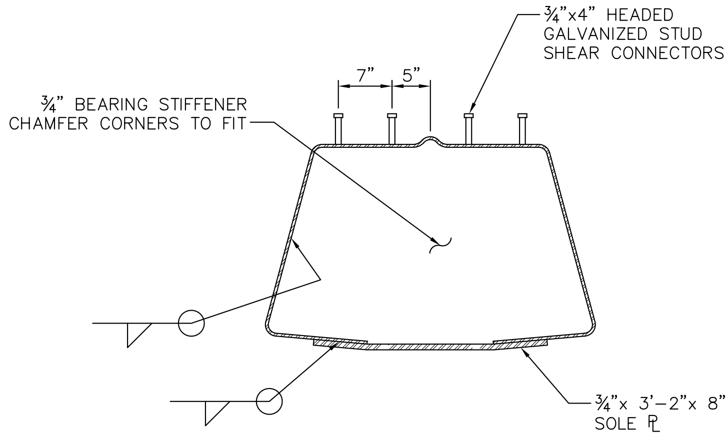
The design of the $1.7 million project (including roadway construction and approach work) was completed in July of 2010, and the construction contract was awarded to the John Rocchio Corporation that October. All four bridge replacements required thirteen weeks to complete, and the roadway was once again open to traffic in November of 2011. As the structure was the first folded steel plate girder bridge ever constructed and placed in service, MassDOT decided to instrument the bridge components with strain gauges to monitor stresses in the steel plates, deck and closure pours. Performance is currently being monitored by the University of Massachusetts.

MassDOT considers this project a success as a new technology was implemented at a competitive price and resulted in a 28% reduction in the on-site construction schedule when compared to a more conventional adjacent precast concrete box beam alternative. The project has also opened the door for a steel alternative in a span range generally dominated by precast concrete solutions.

Owner
Massachusetts Department of Transportation, Boston

Engineer
Gannett Fleming, Inc., Mount Laurel, N.J.

General Contractor
John Rocchio Corporation, Smithfield, R.I.



MERIT AWARD—Reconstructed Category

ACCELERATED BRIDGE CONSTRUCTION COMMENDATION

EGGNER'S FERRY BRIDGE EMERGENCY REPLACEMENT, TRIGG AND MARSHALL COUNTIES, KY.

On January 26, 2012, an 8,679-gross-ton cargo ship struck a 322-ft-long span of the Eggner's Ferry Bridge.

The bridge carries U.S. 68 and KY 80 over Kentucky Lake on the Tennessee River, and the collision effectively closed the western gateway to the Land Between The Lakes National Recreation Area and the only crossing of the lake in Kentucky.

Through an innovative approach to design and construction, the Kentucky Transportation Cabinet (KYTC), Michael Baker Jr., Inc., and Hall Contracting of Kentucky, Inc., were able to replace the span and reopen the bridge to traffic before Memorial Day that year.

Kentucky Lake is a major navigable reservoir adjacent to the 170,000-acre Land Between The Lakes National Recreation Area, which attracts thousands of tourists each year. The Eggner's Ferry Bridge is a 43-span, 3,348-ft-long bridge that provides a vital access point to the recreation area and an important link in the region's transportation system; the detour around the damaged bridge was 42 miles.

Redundancy was an important part of the solution. The preliminary design of the truss assembly was for a parallel chord truss without verticals. Baker redesigned the gusset plates to make all of them a uniform 0.75-in. thick and similarly specified the use of identical sections for the top chord and end diagonals, the bottom chord, the top bracing and struts, the stringers and the floor beams. Designing the truss with only six sizes of rolled sections helped the steel fabricator, Padgett, Inc., and the steel detailer, Tensor Engineering Company, to expedite the detailing and fabrication of the parts by early April. Baker coordinated closely with Tensor to have the shop drawings completed, reviewed and stamped in less than three weeks. Easily accessible material, simple and repetitive connections and high-tech fabrication were the keys to expediting the project. The 13,000 bolt holes that were used to assemble the truss were drilled using computer-controlled equipment, resulting in zero misfits.

The Eggner's Ferry Bridge rehabilitation project demonstrates the importance of careful coordination with the steel detailer and fabricator and intelligent selection of materials and fabrication details. The use of rolled steel sections in the construction of the new truss eliminated the need for cutting plates and welding, saving valuable weeks of fabrication. Although a slightly heavier truss was used, the consistent sizes of all the components of the new truss ultimately saved days in the fabrication and assembly of the replacement truss. A similar approach could be used by bridge engineers to accelerate the delivery of other bridge replacements or repairs, or even new bridge construction projects.

In addition, lifting a replacement superstructure onto a bridge's existing piers can accelerate construction and minimize the need for lengthy closures, detours, and other traffic disruptions. This project demonstrates that this technique can be used effectively to accelerate repairs to a severely damaged bridge.

On May 15, Hall floated the barge down the lake to the bridge site and used two cranes to lift the new truss from the barge onto the existing piers. The installation of the stay-in-place forms and studs and the pouring of the 6.5-in.-thick concrete deck were completed by May 20. The guardrail was installed and the bridge was opened to traffic, with a celebration by the governor, local officials and the community, on Friday, May 25—two days ahead of schedule.

For more on this project, see "Down but not Out" (11/2012).

Owner

Kentucky Transportation Cabinet – District 1, Paducah, Ky.

Engineer

Michael Baker Jr., Inc., Louisville, Ky.

General Contractor

Hall Contracting of Kentucky, Inc., Louisville

Steel Team

Fabricator

Padgett, Inc., New Albany, Ind. (AISC Member/NSBA Member/AISC Certified Fabricator)

Detailer

Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member/NSBA Member)

MERIT AWARD—Special Purpose Category

CHRISTINA AND JOHN MARKEY MEMORIAL PEDESTRIAN BRIDGE, REVERE, MASS.

From redevelopment comes new life—and sometimes a first.

The $1.8 million Markey Bridge is the first cable-stayed pedestrian-only bridge in Massachusetts and has already become an important link between the MBTA Blue Line Wonderland Station in Revere, Mass., and Revere Beach, America's first public beach (established in 1896). Completed last July, the bridge is part of the Revere Transit and Streetscape Project, which was conceived as part of a redevelopment plan for the areas surrounding the Wonderland Station.

The final design and construction was completed through a design-build contract, and the cost of the bridge did not exceed the original budget and completion time. The main span of the bridge crossing Ocean Boulevard is 107 ft and the overall length is 151 ft. The bridge was designed to create a visual statement from a distance providing enhanced and open views of the Atlantic Ocean, and construction had to be coordinated with accessibility to adjacent streets and the beach, which increased the project's complexity.

A pair of 52-ft-tall outward-inclined towers frame the access to the beach and its historic pavilions. All steel components of the bridge are tapered/angled by design, which allows for unique perspectives from several vantage points. The walking surface is 12 ft wide between stainless steel railings that complement the inclination of the towers. Energy-efficient LED aesthetic lighting has been integrated into the railings, enhancing the appearance of the crossing at night. All steel components of the bridge have been treated with a duplex hot-dip galvanizing process to protect them from exposure to the marine environment. Pedestrian traffic between the transit facility and the beach has increased substantially since the bridge opening, and a new hotel is planned to open adjacent to the landmark footbridge in the near future.

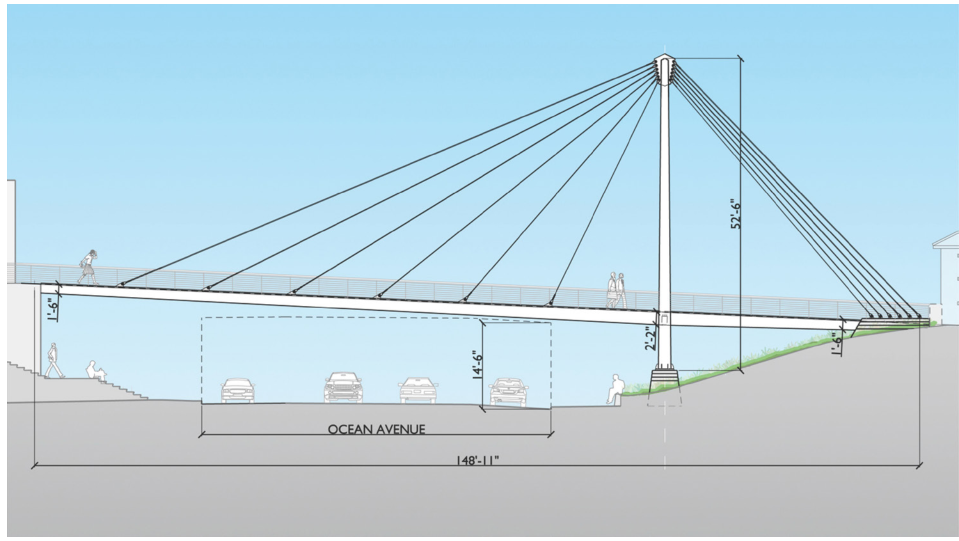
Owner
Massachusetts Department of Conservation and Recreation, Boston

Engineer
AECOM, Boston

Architect
Rosales + Partners, Boston

General Contractor
Suffolk Construction Company, Boston

Steel Fabricator and Detailer
CIANBRO Corporation, Pittsfield, Maine (AISC Member/NSBA Member/AISC Certified Fabricator)



SUSTAINABILITY COMMENDATION

KEENE ROAD BRIDGE, RICHLAND, WASH.

An abandoned Union Pacific Railroad steel box bridge has gained new life with its conversion into a major vehicular traffic bridge in the City of Richland, Wash.

This project required retrofitting the railroad bridge as the final step in completing the Keene Road Corridor, which now serves as a major east-west arterial in the rapidly growing Tri-Cities area of Washington State.

KPFF provided the design expertise for the project, which has been praised by civic leaders and state transportation officials alike for recycling a bridge that had been out-of-service for decades. The retrofitted bridge was designed to carry two westbound traffic lanes as well as a shared-used pedestrian and bicycle pathway across Interstate 182. The newly retrofitted bridge is parallel to Keene Road's preexisting vehicular bridge, which previously carried both east- and westbound traffic over the interstate.

The Union Pacific Railroad Bridge, originally built as a four-span, 412-ft-long steel box structure, had not been under railroad loading since its construction in 1981. The final bridge required an additional 160 tons of steel in addition to the 300 tons that were part of the existing structure. KPFF's winning design was a steel overhang frame, or steel outrigger design, to support the widened portion of the deck. Not only was this the least expensive of the four options considered, but it also offered significant advantages over the other alternatives (a two-span steel girder, four-span steel girder and rebar tie steel overhang frame). The steel outrigger design made the best use of the existing steel box reserve capacity, which was originally designed for heavier railroad loading. The design live load of a train is five times the load considered for truck vehicles on a bridge.

As noted, KPFF partially used the original concrete deck but didn't want to count on the deck to resolve the tension forces between the outriggers. So a steel plate was installed that crossed the top of the box and attached to each outrigger. This adjustment allowed a major part of the original deck to remain in the design.

The railroad tracks of the old bridge were originally positioned within the boundaries of the steel box girder, which meant that the bridge experienced "zero" torsion. KPFF's design doubled the width of the bridge, which in turn located traffic lanes—and their loads—outside the box girder and created significant torsion. To account for the added torsion, KPFF reinforced the existing internal crossframes of the box girder, a treatment that was never part of the original railroad bridge design.

Construction began in August 2011 and proceeded with a minimal number of traffic disruptions—unusual for a bridge project over a major interstate. The bridge officially opened to the public September 28, 2012.

Owner
City of Richland, Wash., Civil and Utility Engineering

Engineer
KPFF Consulting Engineers, Seattle

General Contractor
West Company, Inc., Medical Lake, Wash.

Steel Team

Fabricator
Rainier Welding, Inc., Redmond, Wash. (AISC Member/AISC Certified Fabricator)

Detailer
Adams & Smith, Inc., Lindon, Utah (AISC Member)

ACCELERATED BRIDGE CONSTRUCTION COMMENDATION

130TH STREET AND TORRENCE AVENUE RAILROAD TRUSS BRIDGE, CHICAGO

The intersection of 130th Street and Torrence Avenue in Chicago serves approximately 38,000 vehicles a day, including traffic to and from the nearby Ford Motor Company Plant.

In addition, more than 50 freight trains cross on two at-grade Norfolk Southern (NS) tracks near the intersection, making it a major bottleneck for both rail and vehicular traffic. To eliminate these conflicts, a three-tiered grade separation design was developed for the intersection, and the new Chicago, South Shore & South Bend (CSS&SB) commuter/freight railroad truss is a key component.

The complex reconfiguration involves 130th Street and Torrence Avenue being realigned and lowered below the existing NS tracks. Two new NS structures are being constructed on new alignments and the new CSS&SB structure is already in place on its new alignment. Once fully completed, the project will provide a three-tiered grade separation to relieve traffic congestion and improve the efficiency of rail service in the area. Making sure all the project components fit in this complex puzzle while maintaining all rail traffic required the CSS&SB railroad truss span to be constructed first.

The preliminary design, geometry and location of the truss were based on minimizing impacts to railroad operations during construction; meeting NS horizontal and vertical requirements at both the existing and proposed alignments; tying back into the CSS&SB existing tracks while accommodating a track spiral; and accommodating the proposed widened and realigned Torrence Avenue.

At the end of preliminary design, the proposed CSS&SB structure consisted of a 368-ft-long truss with abutments skewed at 45°; the skew was implemented to have the shortest span possible. During the early stages of the final design phase, other geometric and logistical constraints by the site and stakeholders surfaced, requiring the geometry of the truss to be revisited. The detailing and fabrication of the skewed portal frames of the truss were found to increase the cost of the truss and make fabrication and construction more complex. With accelerated bridge construction (ABC) techniques already approved by major stakeholders, it was also noted that maintaining a skewed truss would make installation more challenging as the self-propelled mobile transporters (SPMTs) would have to guide the truss into place while moving on a diagonal. It was determined that a longer truss with squared abutments would provide a more economical design and would better facilitate construction.

The elimination of the skew had numerous advantages. The volume of concrete required at the abutments was reduced by approximately 30% due to the reduced width of the truss substructures. The end floor beam span was also reduced from approximately 57 ft, 8 in. to 40 ft, 2 in., eliminating the need for an intermediate bearing for the floor beam. The revised and final layout of the truss resulted in a 394-ft span center to center of bearings with supports perpendicular to the structure. The longer truss span required the east abutment to shift a couple feet to the east due to an increase in bearing size from the size estimated during preliminary design. This shift brought the track closer to the truss due to the spiral curve at the end of the truss span. Because of this, the engineer had to make sure the bridge was wide and tall enough to meet the railroad's clearance requirements, and the width of the truss increased from 36 ft, 8 in. to 40 ft, 2 in. center to center of trusses.

The use of high-performance steel was the best, most durable and economical material choice for the truss bridge. It extended the bridge's expected life to 100-plus years and reduced long-term maintenance. This massive double track, ballasted deck, through truss is just a part of the larger complex grade separation structure, which also includes five approach spans consisting of 54-in.-deep pre-stressed box beams. The truss substructure consists of full height concrete piers supported on driven steel piles. An excavation support system was required to protect the existing NS tracks during construction of the new piers.

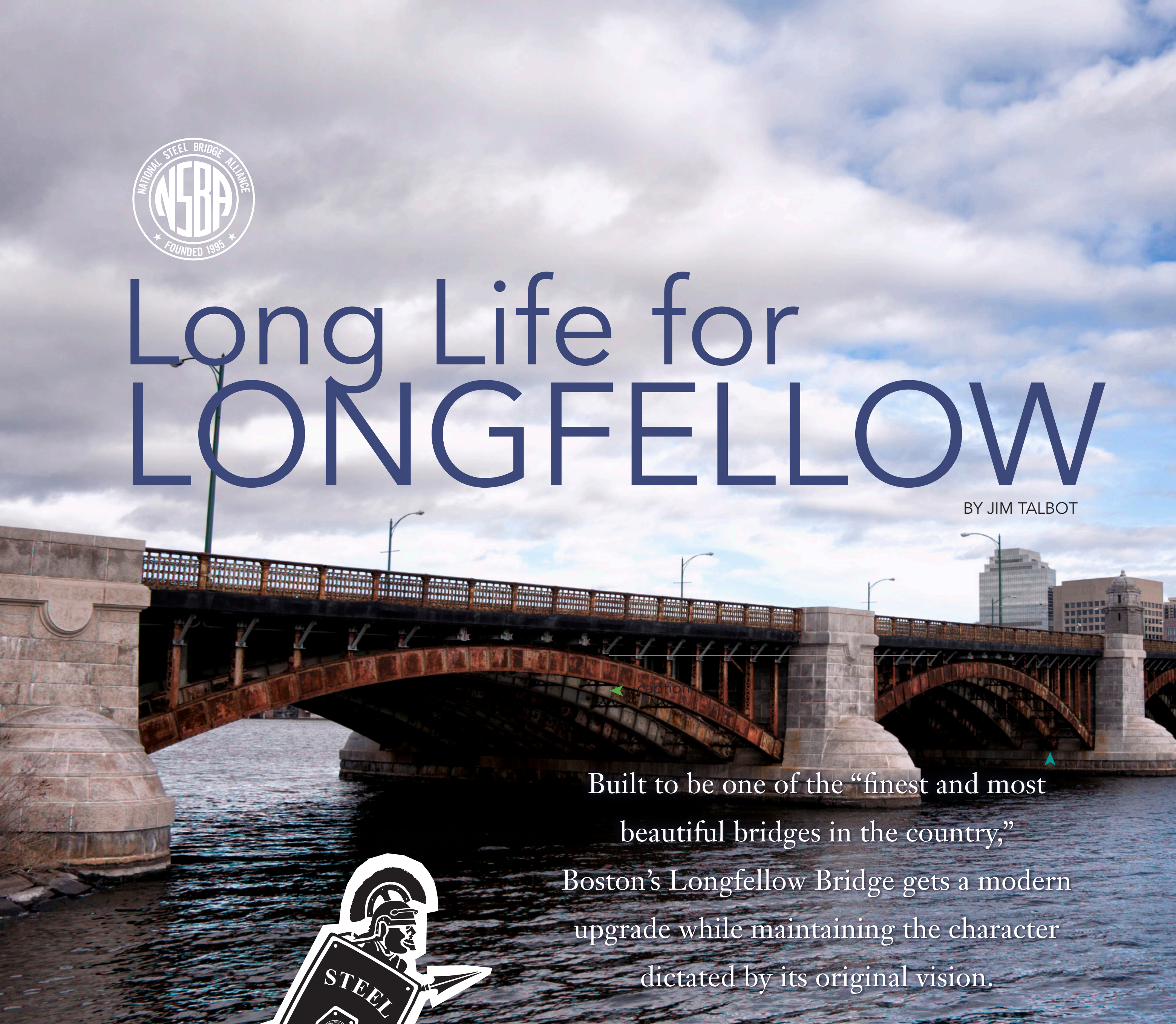
Once the truss was in place, the contractor and railroad teams continued to work on the bridge, placing the ballast and ties on the truss, installing the catenary wires that power the CSS&SB trains and putting the finishing touches on the truss. On October 25, 2012, the first CSS&SB train crossed the new railroad truss bridge.

For more on this project, see "Big Roll" (03/2013).

Owner
Chicago Department of Transportation – Division of Engineering, Chicago

Engineer
Alfred Benesch & Company, Chicago

General Contractor
Walsh Construction Company, Chicago



Long Life for LONGFELLOW

BY JIM TALBOT

Built to be one of the "finest and most beautiful bridges in the country," Boston's Longfellow Bridge gets a modern upgrade while maintaining the character dictated by its original vision.

STEEL CENTURIONS
SPANNING 100 YEARS

Our nation's rich past was built on immovable determination and innovation that found a highly visible expression in the construction of steel bridges. The Steel Centurions series offers a testament to notable accomplishments of prior generations and celebrates the durability and strength of steel by showcasing bridges more than 100 years old that are still in service today.

SOME BRIDGES are downright poetic.

The Longfellow Bridge, which opened on August 3, 1906—and was formally dedicated on July 31, 1907—joins Boston and Cambridge over the Charles River. Originally called the Cambridge Bridge, it became the Longfellow Bridge in 1927 to honor Henry Wadsworth Longfellow; his poem *The Bridge* celebrated its timber predecessor, the West Boston Bridge, built in 1793. Locals often call the Longfellow Bridge the "Salt and Pepper Bridge" because the four ornate central granite towers look like shakers.

At the turn of the century, 33,000 people a day passed over the old West Boston Bridge. In modern times the steel and granite Longfellow Bridge carries 28,000 vehicles, 90,000 transit users and numerous pedestrians and bicyclists daily. However, this has temporarily changed during the $255 million, three-and-a-half-year project to rehabilitate the bridge and restore its historic character.

This project, scheduled for completion in 2016, will repair structural deficiencies, restore historical features and widen pedestrian walks and bicycle lanes. To maintain historic accuracy, rivets rather than high-strength bolts will replace failed rivets. The project will also restore or replicate the original or-

Boston's Longfellow Bridge opened in 1907 and is currently undergoing a rehabilitation project, which is scheduled for completion in 2016.

The bridge is colloquially called the "Salt and Pepper Bridge" thanks to the ornate granite towers that resemble shakers.

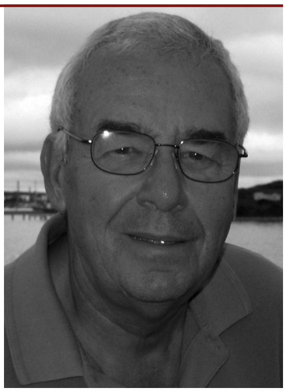
nate pedestrian railings (some of which were stolen and sold for scrap).

Powering Up

In 1889 the street railways of Boston switched from horse-driven to electrical power. Traffic from Boston into the suburbs dramatically increased. By 1894 gridlock slowed service and became a constant irritation to railway commuters. Elevated railways alleviated conditions for a few years, but by the end of the 19th century, Boston, Cambridge and the Boston Elevated Railway Co. requested that the state authorize construction of a new bridge at or near the West Boston Bridge that connected the two cities. The request was granted and led to the formation of the Cambridge Bridge Commission.

The legislation called for the new bridge to be suitable for all the purposes of ordinary travel between the cities, including the elevated and surface cars of the railway company. It also specified a drawbridge

Jim Talbot is a freelance technical writer living in Ambler, Pa. You can reach him at **james.e.talbot@gmail.com**.



Including approaches as well as an extension in 1959, the bridge is nearly a half-mile long. A 105-ft deck accommodates two railway tracks down the center, two traffic lanes on each side and sidewalks for pedestrians and bicycles.

no less than 105 ft wide with masonry piers and abutments, along with a superstructure of iron or steel or both. The Commission appointed Wilham Jackson as chief engineer, who then engaged Edmund M. Wheelwright as consulting architect.

A controversy erupted over designs for a draw versus a draw-less bridge. Commerce on the Charles River had substantially slowed and been replaced by railroads, but the U.S. War Department would have to approve a draw-less bridge, which was considered doubtful and would take years. Despite this, the Commission voted for the draw-less design and petitioned the state to permit the change, which was granted. In early February 1900, bills were introduced in the U.S Congress for a draw-less bridge, the War Department agreed to it on February 14 and Congress voted to approve the bridge, signed by President William McKinley, on March 29.

Best Bridge

Wheelwright was said to have been inspired by the 1893 Chicago World's Fair, which celebrated the 400th anniversary of Christopher Columbus' arrival in the New World, and wanted to emulate the great bridges of Europe. Additionally, the Commission intended to make the new bridge "one of the finest and most beautiful structures in the country." The four central towers are the bridge's most distinctive feature and bear the granite seals of Boston and Cambridge set above ornate carvings of a Viking ship's prow, a reference to a voyage by Leif Eriksson up the Charles River at the turn of the first millennium.

The superstructure over the water consists of 11 open-spandrel steel arches, ranging in length from 101 ft at the abutments to 188 ft at the center. The arches, weighing nearly 8,000 tons, rest on the ten piers and two large abutments and provide about 26 ft of clearance over mean high water under the central arch. Two large central piers—188 ft long by 53 ft wide—feature the architecturally prominent ornamental stone towers.

Including approaches as well as an extension in 1959, the bridge is nearly a half-mile long. A 105-ft deck accommodates two railway tracks down the center, two traffic lanes on each side and sidewalks for pedestrians and bicycles. The graceful 3% grade rising and descending from a central point was considered the limit for heavy teams of horses.

Each arch span consists of 12 two-hinge steel girder ribs. The plate girders range in depth from 3 ft to 4 ft, with the larger depths toward the center. Rib spacing depends on the expected design loads—one under each sidewalk, three under each roadway and four under the railway tracks. Lattice struts and diagonal rods brace the ribs, and a cast steel shoe weighing about 2 tons supports each side of a rib.

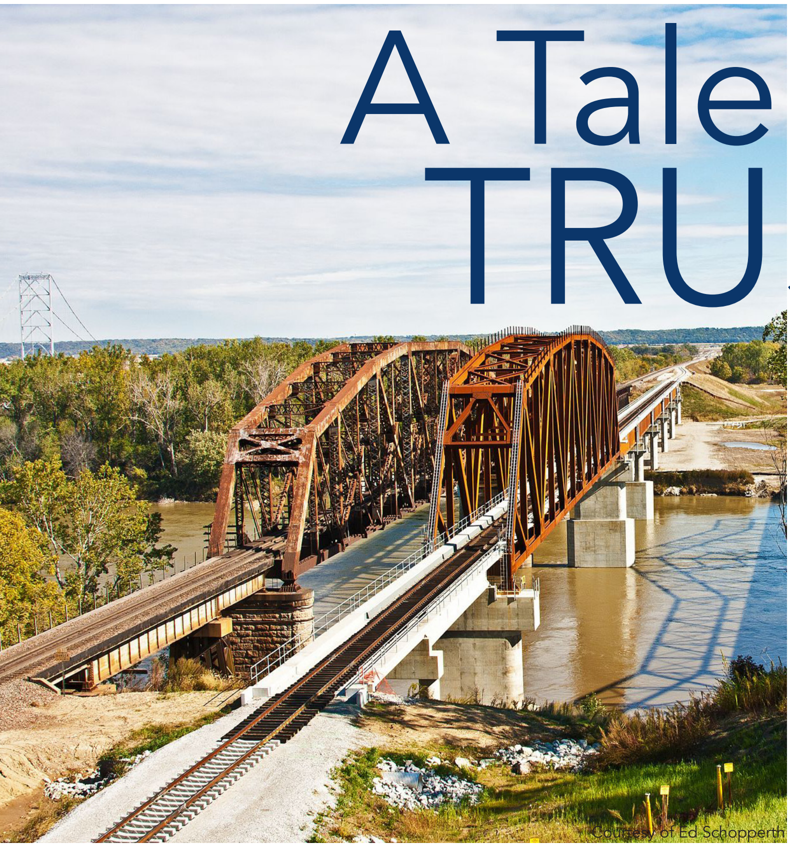
Vertical posts spaced evenly along the arches extend from the top rib flanges. Transverse 15-in. steel I-beams riveted to the top of the posts serve as floor beams. Longitudinal 12-in. I-beam stringers are framed to the floor beams or rest on them. Except for the space allocated to the railway tracks, buckle plates were riveted to the floor beams and stringers to serve as roadway surface and as lateral bracing for the floor system. Contractors paved the original roadway with granite blocks, 6 in. deep, to provide purchase for horses. The blocks rested on sand over a concrete base, which in turn covered the buckle plates.

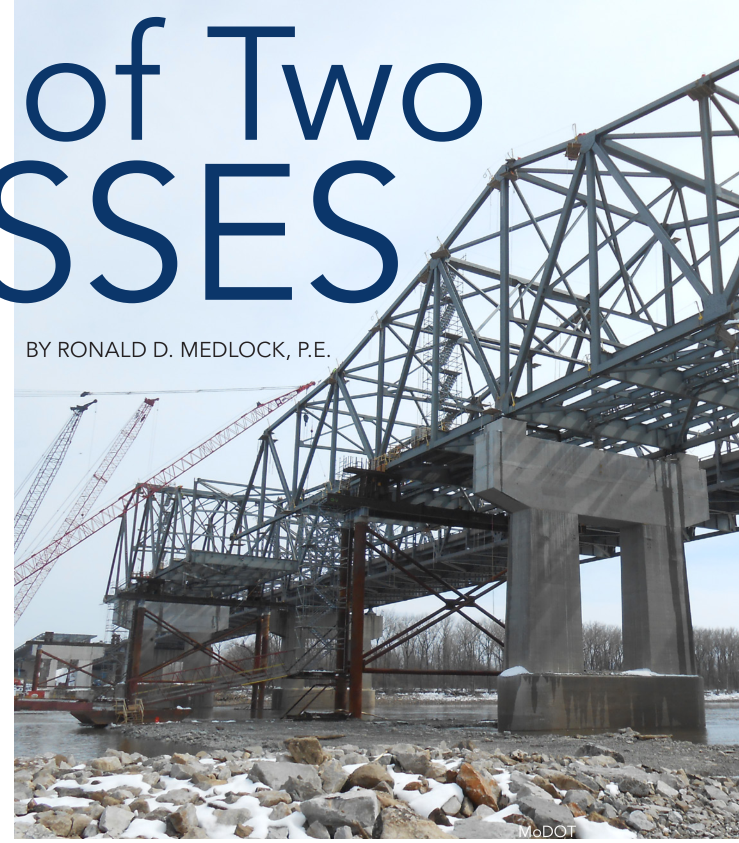
The piers and abutments consist of concrete masses of similar design supported by piles driven into the bolder clay to bedrock. Heavy facings of granite cover the piers and abutments above the foundations. The piers are hollow and concrete cross walls connect the two sides of the piers on the lines of the ribs and skewbacks that transmit the arch thrust to the foundations; the cross walls opposite the four center ribs merge into one thick wall. The masonry above the foundation capstone and arch skewbacks serves to carry the deck as it passes over the piers. These are also hollow, containing concrete interior walls where necessary to stiffen the walls and support deck loads.

Recent Rehabilitation

The Massachusetts Department of Transportation is undertaking the three-and-a-half-year rehabilitation project, which includes improving multi-modal access and bridge-to-city-street connections to meet ADA accessibility guidelines. The deteriorated structural elements will be carefully rehabilitated while preserving and restoring the bridge's distinctive architectural features. The project includes:

A Tale of Two TRUSSES





BY RONALD D. MEDLOCK, P.E.

The enduring nature of an "old-fashioned" design is put on prominent display in two truss bridges spanning the Missouri River.

IN THE DAYS BEFORE welded girders, truss bridges were often the design of choice for bridges needing to span lengths exceeding the span capacity of rolled beams. With the advent of welded girders, this trend changed and truss designs declined in popularity.

While some may consider truss bridges to be relegated to the category of "yesterday's design," in reality truss bridges are alive and well and for very good reasons. Two recent bridge construction projects that cross the Missouri River exemplify this: one for vehicular traffic and one a railroad bridge.

Ronnie Medlock (rmedlock@high.net) is the vice president of technical services with High Steel Structures, LLC.

The Blanchette Bridge

A continuous three-span truss bridge measuring 1,360 ft long, the Blanchette Bridge crosses the Missouri River westbound on I-70 at St. Charles, Mo. Built in the late 1950s, in recent years the Blanchette Bridge required frequent repairs. It became apparent that the 55-year-old bridge needed major refurbishment to keep it operational and safe.

According to Thomas J. Evers, P.E., Missouri Department of Transportation's area engineer for St. Charles County, this project had an aggressive schedule from the very beginning.

"During the design phase, we had originally considered simply rehabilitating all of the existing steel in place," he said. "But after doing a cost analysis, we determined that replacement of most of the structural steel would save in future maintenance costs and extend the overall life of the bridge by 25 more years than originally thought."

The $64 million rehabilitation began in November 2012. Fabricator High Steel Structures, LLC, supplied the entire truss structure above the bridge bearings, a total of more than 3,355 tons of steel. (In a separate contract, DeLong's, Inc., supplied the steel for the approach spans.)

The steel used was A572 Grade 50 with an inorganic zinc primer applied in the shop; the second and third coats of paint were applied in the field once the bridge was erected. The project was detailed by Candraft Detailing, Inc., and High Steel fabricat-

All images on this page: MoDOT

The 1,360-ft-long Blanchette Bridge crosses the Missouri River westbound on I-70 at St. Charles, Mo.

Far left: The Burlington Northern Santa Fe Railway has crossed the Missouri River at the Plattsmouth Bridge since 1879.

ed it with CNC equipment. (High Steel fulfilled its role in fabricating, painting and shipping the truss members by March 2013.)

Transportation required considerable coordination by High Steel's transportation team, High Transit. Fortunately, typical truss bridge design reduces the cost of shipping freight, as a larger percentage of members can be transported on conventional equipment that doesn't require escort vehicles. High Transit used its own drivers on some of the longer specialized trailer loads and also used independent carriers to handle the high volume of loads and the long cycle time involved in the distance to and from the project site.

Crews installed approximately 2,200 pieces of steel for a total weight of 3,250 tons in the truss and 750 tons in the approach girders.

During construction, the Missouri Department of Transportation applauded the contractor, Walsh Construction Company, for all of their hard work under difficult weather conditions.

"We opened this bridge less than 10 months after we closed it," explained Evers, "During those months, this team fought record-low Missouri River levels in December 2012, which prevented the use of barges and forced the construction of a causeway. This team also had fought near record spring flood levels in early 2013, forcing them out of the water and out from under the bridge entirely. The spring also brought a tornado through the project, which caused some minor damage."

The bridge opened to traffic nearly three months ahead of schedule on August 24, 2013.

Taking down the original Blanchette Bridge. The new bridge opened less than 10 months after the original was closed.

Crews installed approximately 2,200 pieces of steel for a total weight of 3,250 tons in the truss and 750 tons in the approach girders for the Blanchette Bridge project.

The original Plattsmouth Bridge, built in 1879, was renovated in 1903, and in 1976 the west approach was replaced and the alignment was straightened to eliminate a 12° curve by building a new deep cut.

The Plattsmouth Bridge

The Burlington Northern Santa Fe Railway has crossed the Missouri River at the Plattsmouth Bridge since 1879, the year it replaced a ferry operation with the completion of two Whipple Through-Truss spans. The original bridge was renovated in 1903, and in 1976 the west approach was replaced and the alignment was straightened to eliminate a 12° curve by building a new deep cut.

After numerous renovations and updates over more than a century, it was time to replace the railroad bridge as it crosses from Plattsmouth, Neb., to Pacific Junction, Iowa. According to BNSF, the total project cost was $46 million, which includes funds allocated to bridge design in 2011 and construction in 2012 and 2013.

"For this project, constructing a new bridge was more cost-effective than restoring the existing bridge," said BNSF project engineer Mike Schaefer. "Over the past century we've seen tremendous improvements in construction and materials."

According to Larry D. Woodley, director of bridge construction over the project for BNSF, the railroad typically specifies a truss design for any bridge span greater than 200 ft long, so the 400-ft navigation channel of the Plattsmouth Bridge necessitated using a truss.

The bridge has a concrete deck-plate girder approach and was stick-built on site on the new piers. To help improve velocity, switches were installed on each end of the new bridge to allow lighter, empty trains to use the existing bridge.

Ames Construction was awarded the contract to build the new 1,683-ft bridge 60 ft north of the existing bridge. High Steel Structures provided 1,213 tons of A588 Grade 50W fracture-critical steel for the railroad truss, while Capital Contractors, Inc., provided 2,046 tons of plate girders for the approach spans.

High Steel began work on the 400-ft truss bridge span in March 2012 and the last delivery was completed February 2013. The company provided all of the truss bridge components, including the truss girders, floor system, sway framing, upper bearing block and bridge inspection rails. At the customer's request, High Steel also performed a 100% check assembly of the rocker pin bearing assemblies in the shop prior to shipment and installation in the field.

One of the key challenges was completing the check assembly on the truss sides in the yard prior to disassembly and shipment to Nebraska. Delivery was coordinated with the project field assembly teams, with shipments leaving three days prior to the need-by dates at the site.

Weather was another concern. With winter approaching, deliveries started the last week of October 2012 and continued throughout the winter until February, when the last of more than 60 trailer loads were delivered to the job site. The loads traveled through seven states and logged more than 1,200 miles to the site each way.

The new Plattsmouth Bridge carries nearly 50 trains daily and provides approximately 400 ft of clearance for river traffic.

High Steel provided 1,213 tons of fracture-critical steel for the railroad truss, while Capital Contractors provided 2,046 tons of plate girders for the approach spans.

The new Plattsmouth Bridge carries nearly 50 trains daily, including coal, mixed freight, intermodal and Amtrak and provides approximately 400 ft of clearance for river traffic.

As we can see by looking at these two Missouri River bridges, trusses remain an impressively relevant and economical choice for vehicular and railroad bridges with longer span lengths. ■

Blanchette Bridge

Owner

Missouri Department of Transportation (MoDOT)

General Contractor

Walsh Construction Co.

Structural Engineer

Jacobs Engineering Group, Inc.

Erection Engineer

Collins Engineers, Chicago

Steel Team

Fabricators

Truss spans: High Steel Structures, LLC, Lancaster, Pa. (AISC Member/AISC Certified Fabricator/NSBA Member)
Approach spans: Delongs, Inc., Jefferson City, Mo. (AISC Member/AISC Certified Fabricator/NSBA Member)

Detailer

Candraft Detailing, Inc., New Westminster, B.C., Canada (AISC Member)

Plattsmouth Bridge

Owner

BNSF Railroad, Fort Worth, Texas

General Contractor

Ames Construction, Burnsville, Minn.

Structural Engineer

TranSystems, Kansas City, Mo.

Steel Team

Fabricators

Truss spans: High Steel Structures High Steel Structures, LLC, Lancaster, Pa. (AISC Member/AISC Certified Fabricator/NSBA Member)
Approach spans: Capital Contractors, Inc., Lincoln, Neb. (AISC Member/AISC Certified Fabricator/NSBA Member)

Erector

Davis Erection, Omaha, Neb. (AISC Member)

Detailer

Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member)

A look at the ins and outs of the hot-dip galvanizing process.

GALVANIZING Illustrated

BY GEOFF WEISENBERGER

HOT-DIP GALVANIZED steel, known for its silver-gray hue, sports a protective zinc coating that prevents oxidization. Zinc and iron react to one another through a diffusion process, creating a four-layer zinc iron alloy. This layer of protection is particularly suitable for steel that must withstand harsh, outdoor environments where it is exposed to the elements. And it can be used on myriad types of steel, not just structural.

But how does the hot-dip galvanizing process work? Following is a photo tour of AISC member AZZ Galvanizing's Goodyear, Ariz., plant. By the end, you'll have a better understanding of how steel goes from uncoated to zinc-encased and ready to ship. ■

Geoff Weisenberger (weisenberger@aisc.org) is *Modern Steel's* senior editor.

The galvanizing process was discovered in the 1700s and the basics haven't changed much since. The mixture that the steel is dipped in is 99% pure zinc, along with a small amount of aluminum (which gives it a shine) and other proprietary chemicals.

Steel comes into the facility in various stages of cleanliness; the Goodyear facility has a sandblasting building for steel that needs to be blasted. All steel batches go through a series of tanks or "baths." From the staging area at the beginning end of the plant, the steel takes its first bath in a high-pH (above 13) caustic dip, which removes oil, grease and dirt. Sodium hydroxide is the primary chemical in the dip, which also includes proprietary emulsifiers and surfactants. The metal rests in the caustic bath for 10 minutes to an hour, depending on its condition. After the batch is dipped in the caustic fluid, it must be neutralized, so the second bath it takes is in water.

Speaking of water, venting is a crucial step for steel elements that will be put through the galvanizing process, particularly with hollow pieces. When moisture trapped inside an element becomes super-heated, it can generate 3,800 psi of pressure and blow a steel piece apart. AZZ makes sure to check steel for proper venting before putting it through the process. And in cases where steel isn't vented properly, they contact the fabricator and either have them add venting holes or perform the work themselves on-site using torching or drilling, charging the fabricator accordingly.

The third tank is an acid bath, which removes any oxidization. Either sulfuric or hydrochloric acid is used for this "pickling" process; the Goodyear facility uses sulfuric acid. The two acids attack oxide in different ways. Sulfuric finds fissures in the oxide layer, penetrates next to the base metal and removes the oxide layer. Hydrochloric acid is a bit more forgiving on the base metal in that it simply dissolves the oxide layer. The acid bath lasts between 7 and 30 minutes, depending on the metal's rust condition. Metal with heavy oxides might stay in for up to 45 minutes.

Zinc arrives at the facility in approximately 2,400-lb pieces and is added to the kettles regularly as the levels get low; the operators keep the level 2 in. to 3 in. below the lip of the kettle to prevent spillage when elements are dipped. This facility has three kettles in two different buildings, as well as a decommissioned kettle. The two longest kettles—43.5 ft long and 36 ft long—are both 6 ft wide and 9 ft deep, while the third kettle is 23 ft long, 3 ft wide and 6.5 ft deep.

From the pickling tank, the batch goes into another water bath to rinse off the acid. The next and final bath before the actual zinc dip is a low-pH zinc ammonium chloride mixture, which acts as a fluxing agent. It also contains a chlorine salt that encapsulates the metal and prevents it from oxidizing again.

Operators move each batch from kettle to kettle via wired remote control.

Following the flux, it's time for the zinc. The batch is dipped in a kettle that holds, in the case of the largest kettle at the facility, around 1.1 million lb of molten zinc. A blast shield is lowered for the initial dip to prevent splatter on the operators.

The zinc in the kettle is kept at 835 °F. Once the base metal reaches the 835 °F mark, which usually takes about 3½ minutes, the reaction is complete.

The zinc kettle is the most highly skilled position in the shop and operators "finesse" the batches—raising and lowering them into the kettle to make sure the zinc gets into all of the nooks and crannies, tapping them as necessary to remove excess zinc and skimming the top of the tank to make sure that no detritus adheres to the steel as it is brought out of the dip.

The number of times the batch is raised and lowered into the tank (to completely remove trapped skimmings) depends on its geometry, but each batch eventually emerges with a shimmering silver coat.

There is no cure time, but each batch is typically dipped in a vat of water for cooling.

To maximize productivity, the Goodyear plant lines up jobs so that while one batch is in one bath, another batch is in the bath preceding it, and so on. It also bundles its steel orders together to maximize crane capacity. In addition, there are two lifts for the zinc kettle, one at the front and one at the back, so two batches can be hot-dipped simultaneously.

The smaller building employs 7.5-ton cranes while the larger building uses 10-ton cranes to move steel batches down the line. Each batch is tagged for tracking purposes, but the tag is attached high enough so that it is not submerged in any of the tanks or kettles.

Once the steel is galvanized, quality control is essentially built in, as defects or voids in the coating are visible to the naked eye. Deburring is performed outside as necessary.

If there are significant defects in the coating, the steel can be put through the entire process again. The plant also performs various touchup processes as necessary, and there is an outdoor area designated for zinc-rich painting and metallizing (where zinc is sprayed onto the steel) operations.

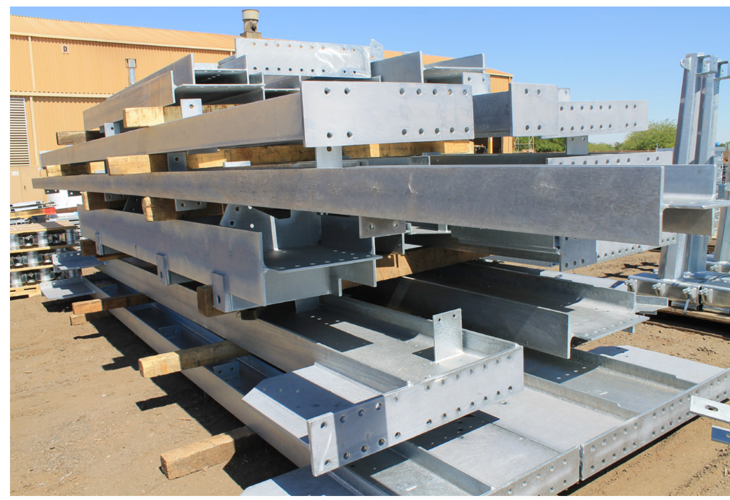
A third type of touchup work involves the application of additional zinc via a zinc stick. This can be done immediately after the dipping and cooling process when the steel is still warm enough for the zinc to be melted on.

Smaller elements, such as bolts, go through the galvanizing process in special spinner baskets in the 23-ft tank. After the zinc dip, the baskets are spun in a special machine to remove the excess zinc.

Some structural steel elements include portions of the surface that are not to be galvanized. These are covered via a special paint that comes off during the galvanizing process but stays zinc-free when it emerges from the zinc kettle.

Once a year the caustic tank solution is pumped over to a rinse tank, and the sludge is removed from the tank, treated and sent to a landfill as a non-hazardous waste. The solution is pumped back over to the caustic tank and rebuilt to operational specifications. The acid is recycled and reused. The Goodyear plant's acid recovery system keeps the tanks free of zinc and iron (contaminants that can contaminate the pickling tank), and the acid tanks are replenished with fresh acid, typically on a daily basis. Water from the caustic rinse and acid rinse tanks is used to build new caustic and acid solutions. The preflux solution and tank go through the same cleaning and recycling process used for the caustic solution and tank.

The turnaround time for a galvanizing job, from the time it arrives from the fabricator to when it is ready to be shipped to a project site or service center, is typically five days.



All zinc used at the plant is 100% recyclable. AZZ removes a slag material called "dross" from the kettles about every two weeks. Dross is created from small particles of iron coming off the steel being dipped; the iron particles are encapsulated by zinc, and because they're heavier than zinc, fall to the bottom of the kettle. The dross is compressed into blocks and sold to a company that separates the zinc from the iron, then sells the zinc back to the galvanizer.

Zinc kettles are typically used for about seven years before requiring replacement.

In addition, zinc oxide that forms during the galvanizing process is ladled off the top of the kettle and processed in a machine that separates the zinc from the zinc oxide. The zinc is returned to the kettle and the zinc oxide material is sold to the same company that recycles the zinc from the remaining skimmings. From there, the zinc oxide can be used in a number of applications, including health-care products, cosmetics, animal feed and paint.

A look at the performance of the national uncoated weathering steel bridge inventory.

TIME Tested

BY JENNIFER MCCONNELL, PH.D., DENNIS R. MERTZ, PH.D., AND HARRY W. SHENTON, III, PH.D.

ALL RESEARCH TAKES PLACE in a lab—of sorts.

For uncoated weathering steel (UWS) bridges, that lab is out in the open, exposed to the elements, in various types of environments across the country.

UWS bridges have now seen domestic use for nearly a half-century, an appropriate time frame for assessing their long-term performance. Such an assessment has been the focus of recent research, "Evaluation of Unpainted Weathering-Steel Highway-Bridge Performance," conducted at the University of Delaware's Center for Innovative Bridge Engineering in partnership with the Federal Highway Administration's (FHWA) Long Term Bridge Performance Program (LTBPP) and Rutgers University. Specifically, UWS performance has been assessed through surveying the varied experiences of 52 US transportation agencies as well as through compiling a national database of UWS bridges and performing a data analysis on the condition of these bridges. In total, the performance of nearly 10,000 structures has been quantified as a result of these efforts.

Qualitative Performance

Through a survey facilitated by the organizational structure of FHWA's LTBPP—which has "state coordinators" in each state, Puerto Rico and the District of Columbia—data has been compiled regarding owners' perceptions on the performance of UWS. Respondents were asked to "briefly describe your general perception of the overall performance of unpainted weathering steel in highway bridges within your agency."

"Overall performance" was defined as performance away from problematic details such as leaking joints, details that trap moisture and debris, etc., because the reasons for inferior performance at the locations of problematic details is relatively well understood and theoretically easy to remedy with sufficient maintenance resources. Rather, a major goal of this survey was to reveal general information on the frequency and characteristics of structures suffering from accelerated corrosion over more widespread areas.

The responses to this question were categorized into the three distinct categories listed below, which emerged as the results were reviewed:

- Entirely Positive (EP): No overall performance problems with UWS indicated.
- Mostly Positive (MP): A generally positive perception of UWS performance was indicated, but some drawbacks were also mentioned.
- Negative: A response indicating a negative perception of UWS performance.

Based on these definitions, Figure 1 (on fthe following page) shows the geographic distribution of the 50 responses to this question (agencies not reporting data for this question are filled with a dashed pattern). The map indicates that 96% of the respondents have a positive perception of the performance of UWS, including 29 of the 50 respondents (58%) being in the EP category. The 38% of respondents in the MP category reported issues typically associated with various specific environments or situations. These

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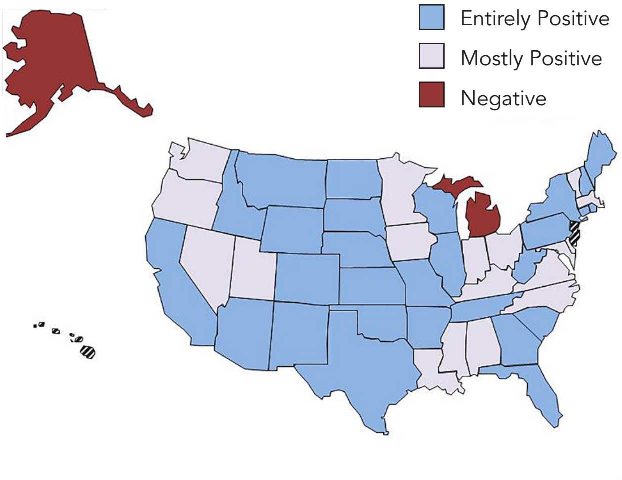


Figure 1. Owners' perception of the performance of UWS bridges in their state.

problematic environments were most often related to the use of deicing agents on underpass roadways. The only two states with a negative perception of UWS were Michigan and Alaska—neither of which has constructed any UWS bridges since guidance on proper UWS maintenance ("Uncoated Weathering Steel in Structures Technical Advisory") was published by FHWA in 1989. (Michigan's newest UWS bridge was constructed in 1983 and all of four of Alaska's UWS bridges were built in 1974 or 1975.)

Quantitative Performance

A national UWS bridge database was created through cooperation with 46 state coordinators and representatives from eight federal agencies who identified the UWS bridges within their inventory. As a relatively simple means to assess the performance of this extensive inventory of UWS bridges, the National Bridge Inventory (NBI) superstructure condition rating (SCR) of each structure was compiled. The SCR is an integer value from 0 to 9 that is meant to describe the overall condition of girders, cross-frames, bearings, etc., with 0 being the worst condition (failed) and 9 being the best condition (excellent). The rating takes several factors into consideration, including fatigue cracks and other visual signs of over-stressed members, damage resulting from vehicular impacts, missing bolts in structural connections and corrosion. From the review of numerous inspection reports of specific structures, it has been observed that the last of these (corrosion) is one of the more common causes of decreasing SCR. Thus, when reviewing these ratings for an extensive sample size of UWS bridges, the authors have shown that these ratings give a general quantitative indication of UWS performance.

The data summary shown in Figure 2 shows that on average UWS bridges perform quite well, with the most populated SCR being 8, which represents "very good" condition, and 50% of the total inventory of UWS bridges having either a SCR of 8 or 9. Furthermore, 95% of the UWS population has a rating of 6 or better, indicating "satisfactory" performance or better. Note that only 1% of the UWS population received a rating of 4 or less. Furthermore, the SCR values of 0 to 3 were not found to be a direct result of UWS or corrosion-related issues; instead, they were most commonly related to un-arrested fatigue cracks in the sample of bridges for which detailed information has been obtained. Figure 3 shows, perhaps unsurprisingly, that a clear factor affecting SCR is the age of the structures. Specifically, a relatively linear decreasing trend in SCR with increasing age is observed, where the average SCR for bridges 10 years old and younger is 8.0 and is 6.5 for bridges 41 years old and older.

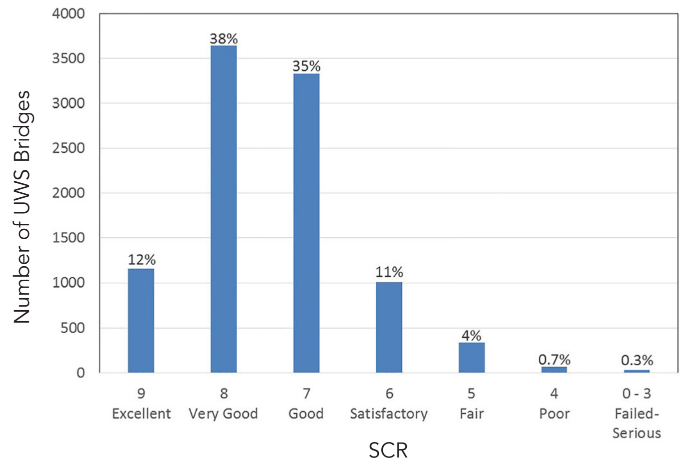
Comparative Performance

The significance of the above data increases when viewed in context relative to other material types. Figure 4 shows the SCR versus age for UWS bridges in two representative agencies (one from an agency in the "entirely positive" category and the other from the "mostly positive" category based on the survey results discussed above) plotted relative to the other steel (OS) bridges in these same agencies. As a simple means to aid in interpretation of and comparison between data sets, trend lines based on linear regression analysis of each data set are added to each of these data series.

In comparing the performance of the UWS and OS data sets, it is observed that in the entirely positive category, the performance trend of the UWS data set is similar to the performance trend of the OS data set, with UWS tracking slightly above. This difference is more pronounced for younger bridges, although even UWS bridges designed prior to the publication of the FHWA UWS technical advisory outperform their OS counterparts. For the mostly positive performance category, it is also observed that the UWS bridges display similar performance relative to their OS counterparts. For these two data sets, the trend lines are very similar, with the UWS trend line being slightly superior to the OS trend line for ages between 1 and 25 years and the OS data set being slightly superior otherwise. However, this finding should be viewed in light of two facts. The first is that even though data is plotted here for ages 1 through 49, there are relatively few (only nine) bridges older than 35 years old, so data for these structures is not statistically

Favorable performance of a UWS overpass.

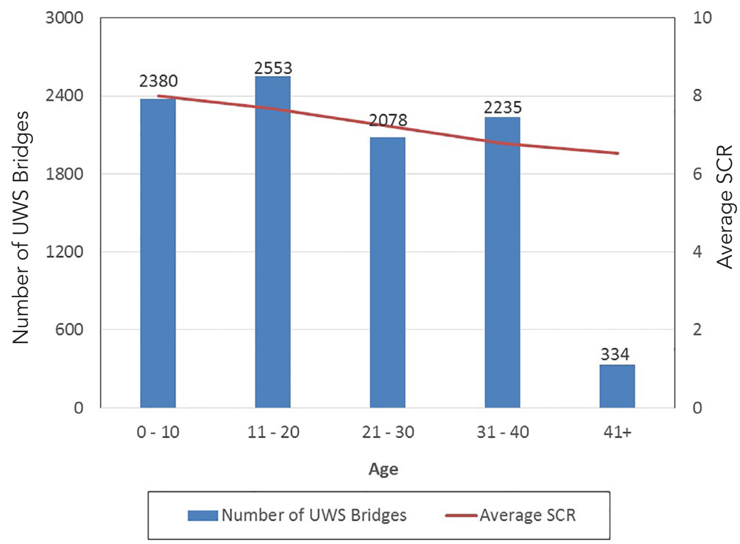
➤ Figure 2. Distribution of UWS population by SCR.



significant in light of the total number of bridges considered in this figure (12,000). The second is that it has been 25 years since the FHWA UWS technical advisory was published. Thus, it is possible that design or maintenance practices implemented since that time would change these trend lines as the newer bridges in this population age in the future.

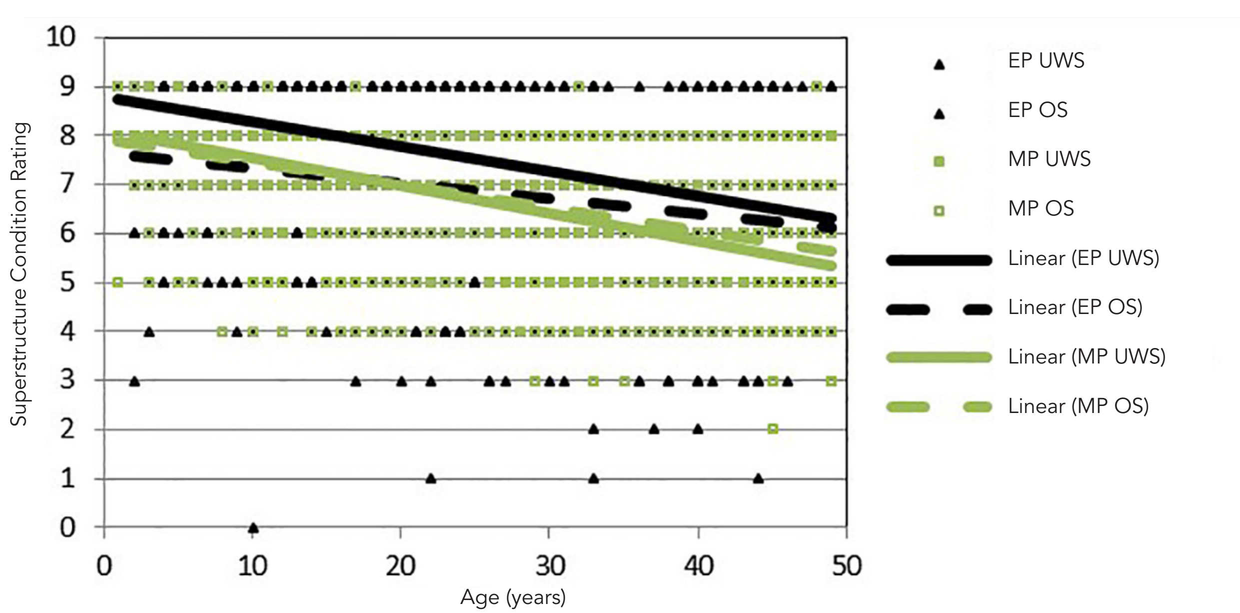
Further Work

As a result of the data presented herein, we have concluded that UWS generally provides reliable performance in highway bridge applications throughout the U.S. Specifically, as a result of the survey of bridge owners, it was found that 96% of the respondents have a positive perception of UWS performance within their inventory and that the remaining two agencies had not built any UWS bridges since 1983—which was, again, prior to the FHWA guidance on this topic being published in 1989. When reviewing the NBI ratings of the structures in the newly created national UWS bridge inventory, it was found that the superstructure condition ratings of the majority of UWS bridges are classified as excellent or very good. While these tend to be newer UWS bridges, UWS bridges that



➤ Figure 3. Distribution of UWS population by age with corresponding SCR.

➤ Figure 4. Superstructure condition rating vs. age, UWS vs. other steel bridges.



have been in service for over 40 years were shown to be also generally performing well.

Furthermore, based on the fact that Figure 4 shows the average performance of UWS is on par with or better than the average performance of painted steel superstructures for the representative agencies evaluated here, we can conclude that when choosing between these two corrosion-control strategies and considering the economic and environmental benefits of UWS bridges, UWS is a sound choice in many different environments. That said, complementary research is recommended to more carefully evaluate potential exceptions to this general statement.

One such research topic has been to analyze UWS performance as a function of climate (see "National Review on Use and Performance of Uncoated Weathering Steel Highway Bridges" in ASCE's *Journal of Bridge Engineering*). This work revealed that UWS bridges generally performed well across all climate categories and suggested that maintenance practices may be a more influential indicator of UWS performance than climate; this latter hypothesis is of interest for future evaluation. Furthermore, the climate analysis to date has consisted of broadly categorizing bridges into regional climate categories. However, recent creation of a geographic information system (GIS) database combining the UWS inventory, climate data and atmospheric chemical concentrations now allows the specific climate conditions (e.g., monthly humidity values, annual snowfall and atmospheric chloride levels) of each UWS bridge to be known, which could reveal new insights on the effects of local climates.

Lastly, field work to more rigorously evaluate specific UWS bridges is also underway, along with a complementary effort to obtain as much information as possible from existing inspection reports of additional UWS bridges so that additional metrics beyond SCR, such as element-level condition state data and visual observations, can be considered. Through such efforts, guidance on expected UWS performance in representative realistic conditions can be obtained, which can ultimately lead to the development of UWS best practices and guidelines. ■

Piece BY Piece

BY MICHAEL P. CULMO, P.E.

Span-by-span bridge construction, using modular steel bridge elements, can serve as a viable and economical bridge-building alternative.

ACCELERATED BRIDGE CONSTRUCTION (ABC) has come a long way in the last 10 years.

And prefabricated, modular elements made with steel beams have been a big factor in making this happen, as they can be used to reduce the weight of the assemblies, thereby making crane installations more cost effective and viable.

Modular steel beam/deck elements generally consist of two or three steel beams with a composite concrete deck cast in the fabrication plant. They are erected quickly and joined with reinforced concrete closure pours made with high-early-strength concrete; a bridge superstructure can be built in as little as two days using this technique.

One of the more successful examples of this method was the 93Fast14 project in Medford, Mass. (a 2012 NSBA Prize Bridge Awards winner), which involved replacing 41 spans on 14 bridges along Interstate 93. The 14 bridge superstructures were replaced during ten 55-hour weekend work periods. The use of structural steel for the beam elements made the project possible since crane capacities controlled many of the sites.

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Span by Span

Let's take a look at the two common ABC methods to design and construct a multi-span bridge. The first is to detail multiple simple spans between supports, sometimes referred to as "span-by-span" construction. Conventional simple-span bridges require expansion joints at each pier—historically a problematic feature of many bridges—as leaking joints, considered by many to be the most common cause of premature bridge deterioration, lead to the corrosion of beam ends and deterioration of the substructures under the joints.

The second method for designing multi-span bridges is to use continuous-span beams, which do not require deck expansion joints at the interior supports, and require less structural steel for a given span arrangement.

Span-by-span beams are simply erected on the substructures without the need for splicing and shoring towers. The problem with leaking deck joints has been addressed by designing these bridges to be either joint-less or continuous for live load by using simple concrete pours at interior supports to eliminate the need for deck expansion joints. Using span-by-span techniques for the superstructure can accelerate the process by eliminating the need for welded or bolted field splices in continuous girders. Beam erection can progress very rapidly as the modular units are inherently stable. Once set, the crane can release the beam without the need for any external bracing.

One method that has been developed to eliminate deck joints on simple-span bridges is "link slab" technology. A link slab is built by simply casting the slab continuously across the pier linking the two spans. The link slab is designed to accommodate the live load rotation of the girders without significant cracking. This is accomplished by debonding a portion of the deck near the support to form the link slab, which acts as a flexible beam. The recommended

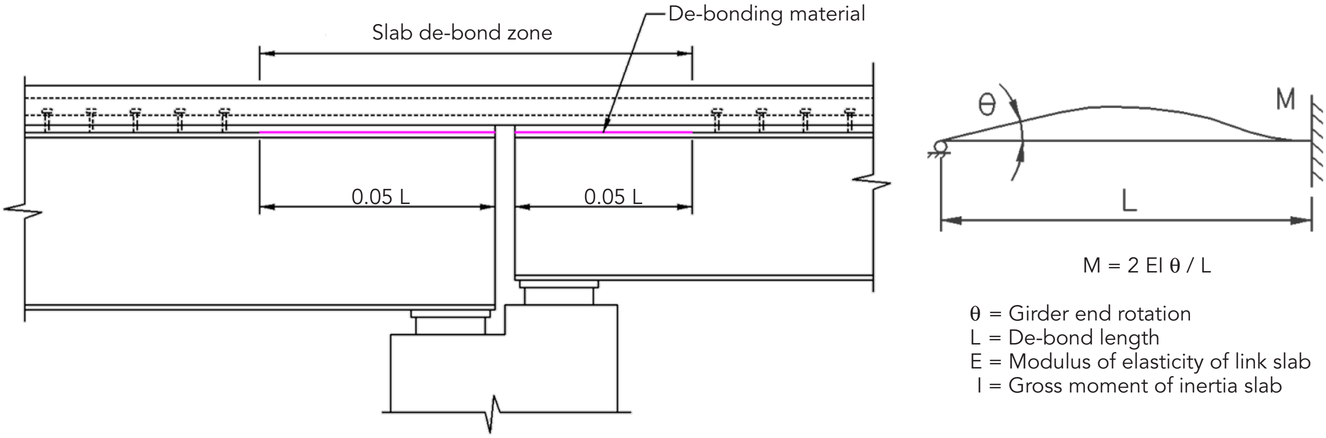
The 93Fast14 Project in Medford, Mass., demonstrated the viability of modular steel bridge construction by replacing 41 spans in ten 55-hour weekend work periods.

length of de-bonding is 5% of the adjacent span on each side of the pier. Keep in mind that link slabs are not a form of continuity. The bending moments in the link slab are much less than typical negative bending moments in continuous girder bridges; therefore, the design of the girders is based on simple-span supports.

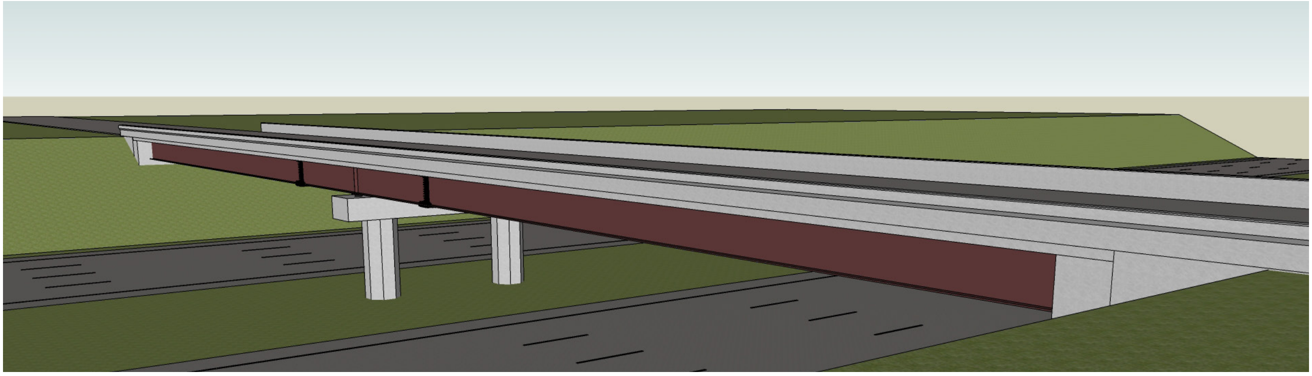
The bending moment in the link slab can be calculated using a simple equation. Reinforcing can then be designed to resist the bending and control cracking. The bending stresses in link slabs are often less than the tension stresses that develop in continuous-span bridges. The same principals of crack control reinforcing design are applied to both.

Greater Efficiency

We are taught in engineering courses that continuous steel girders are more efficient than simple-span girders and that "least weight equals least cost." In principle, these lessons are true. But in order understand the true efficiency of steel bridge construction, the engineer needs to look at the total cost of the bridge, including the cost of connections, construction methods and deck reinforcement. In order to study the efficiency of span-by-span construction, we investigated the preliminary design of a hypothetical two-span bridge. The bridge selected is a typical expressway overpass with equal spans of 122 ft and five girder lines.

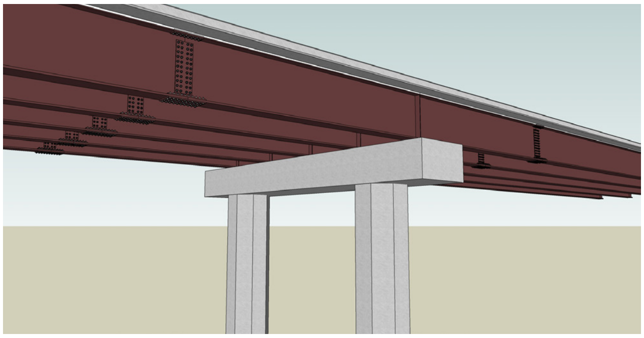


Bridge deck joints can be eliminated at piers through the use of "link slabs."

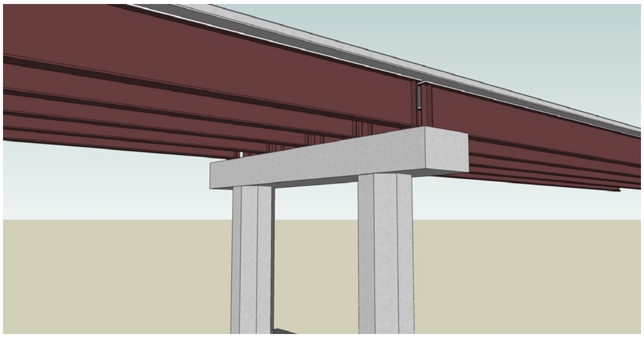


▲ Typical two-span overpass bridge.

▼ Continuous girder with bolted splices.



▼ Simple-span bridge with joint-less deck.



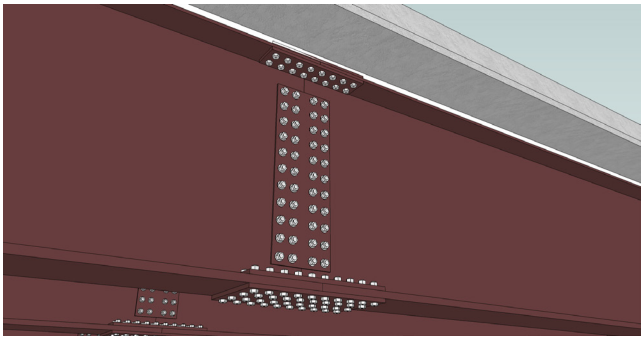
Two bridge types were studied for this structure: continuous girders and simple-supported girders. The NSBA computer program Simon was used to complete a preliminary design of the girders. (Simon is available for free at **www.steelbridges.org** and can be used to design efficient steel girders for simple- and multiple-span bridges based on the AASHTO LRFD *Bridge Design Specifications*.)

The results of the preliminary design showed that the simple-span bridge required 30 more tons of steel at a cost of $70,000 more than the continuous-span option (based on construction costs in the Northeast). The remainder of the study was dedicated to investigating the total cost of the bridge in order to determine if other factors would offset the increased cost for the structural steel.

On such factor was splicing. The 122-ft-long simple-span girders can be shipped in one piece (without field splices), where the continuous girders would need at least one field splice. The study assumed that two field splices would be required for the bridge. It may be possible to build this bridge with one splice, but the length of the pieces would be more than what some permitting agencies would allow.

Another NSBA computer program, Splice, was used to design the bolted splice for the continuous girder study bridge. This program can efficiently design a bolted field splice according to the requirements of the AASHTO LRFD *Bridge Design Specifications*. The final design of the splice included 116 high-strength bolts, and the cost for fabrication and installation of the splice was estimated to be $5,800 per splice (again, based on typical regional construction costs). By eliminating the need for bolted field splices in the span-by-span bridge, an estimated cost savings of $58,000 could potentially be realized.

The *Bridge Design Specifications* require the use of longitudinal reinforcing steel in the negative moment region of continuous girder bridges in order to control cracking due to composite dead load and live load moments. In general, the design of link slabs results in longitudinal reinforcing that is much less than that used in continuous girder bridges. In addition, the link slab reinforcing steel need only be applied over the link slab zone, which is typically smaller than the negative moment region of a continuous girder. For the study bridges, the link slab design saved considerable reinforcing steel when compared to the continuous-span bridge, which equated to an approximate savings of $22,000.



▲ Bolted field splice designed using NSBA's Splice program.

Another avenue of potential cost savings with simple-span construction is erection. Many agencies require the use of shoring towers under bolted splices. Even if shoring towers are not used, the cranes are required to hold the girders until sufficient bolts are installed in the field splices, which is a less efficient process. The potential erection cost savings for the simple-span bridge was estimated to be approximately $30,000.

When it comes to bearings, simple-span construction requires two lines of bearings at the center pier, compared to one line of bearings in the continuous girder bridge. The simple-span bearings are small but there are more to fabricate and install, and the cost of the extra bearings was estimated to be approximately $1,500.

When the above items are accounted for, an estimated net cost savings of $38,500 could be realized for the span-by-span bridge.

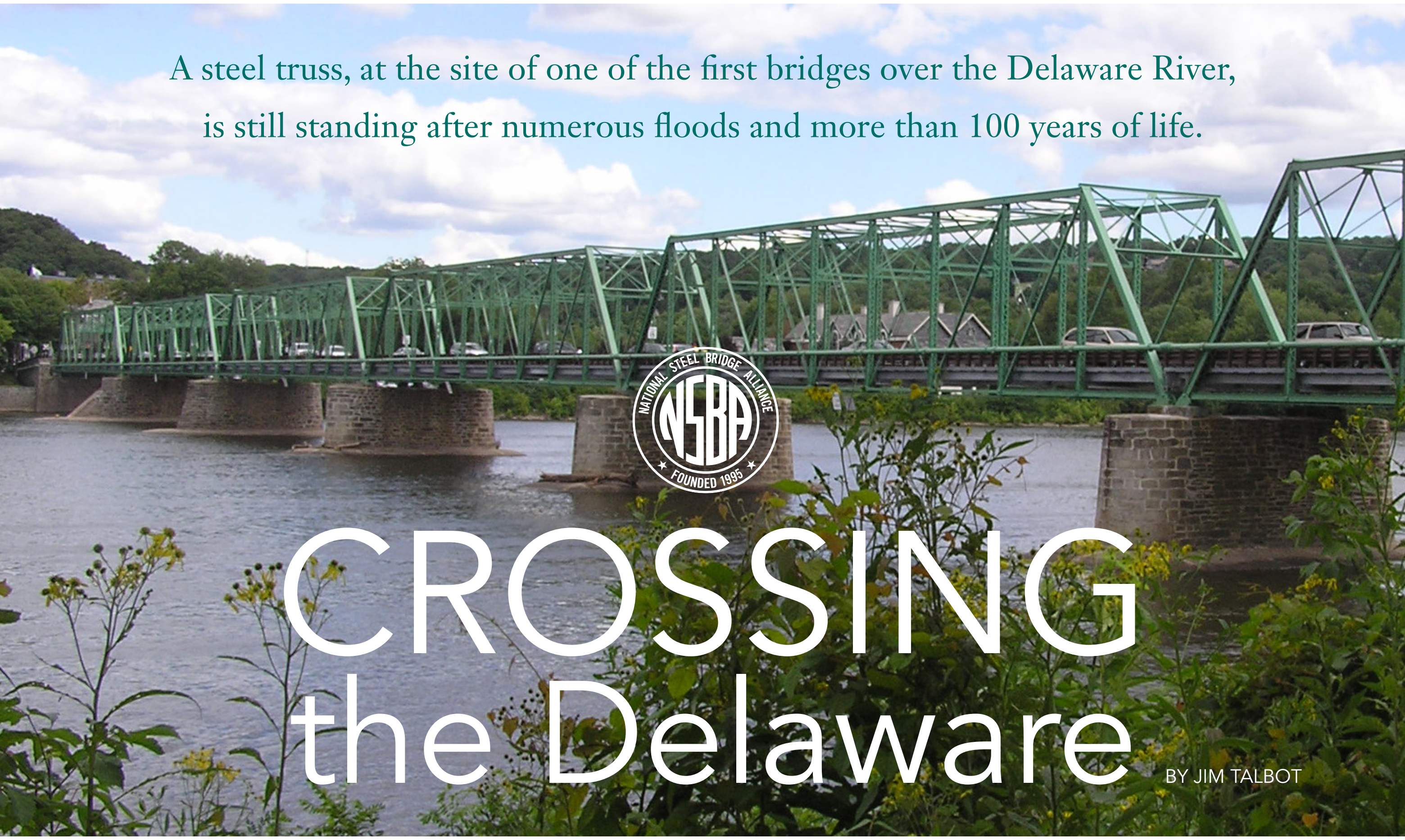
Item	Net Cost Savings
Structural Steel	-$70,000
Bolted Splices	$58,000
Additional Deck Reinforcing	$22,000
Steel Erection Cost	$30,000
Bearings	-$1,500
Net Savings	$38,500

Net cost savings for simple-span construction as compared to continuous bridge construction.

To recap:

1. Continuous-girder spans require less structural steel and fewer bearings.
2. The simple-span construction method may not need bolted field splices, uses less additional deck reinforcement and may be less expensive to erect when compared to a continuous girder bridge.
3. Least weight of structural steel does not always equate to least overall bridge cost.
4. By using link slab technology, simple-span construction can be accomplished with a joint-less deck that is durable.
5. Simply put, simple-span construction is a valuable tool for accelerated bridge construction projects.

This study was limited in that only one bridge was investigated. Other bridge configurations will yield different results. In some cases, a continuous-girder bridge may have a lower overall bridge cost. The conclusion of the study is that simple-span construction should not be ignored due to concerns over the structural efficiency of the girders alone. When total bridge costs are applied, this method can be competitive or even less expensive than conventional continuous-girder designs. ■



A steel truss, at the site of one of the first bridges over the Delaware River, is still standing after numerous floods and more than 100 years of life.

CROSSING the Delaware

BY JIM TALBOT

THE MOST FAMOUS CROSSING of the Delaware River happened in 1776, when America's first president, George Washington, brought troops across the river in a surprise attack against Hessian Forces during the American Revolutionary War.

Nearly 40 years later, in September 1814, a covered span followed suit and became the first bridge to cross the Delaware River that connected New Hope, Pa., and Lambertville, N.J., replacing Coryell's Ferry.

Designed by Lewis Wernwag, a German immigrant and pioneering bridge-builder, the wooden covered bridge was 32 ft wide and had two wagon lanes and two lanes for pedestrians. Flooding carried the bridge away in January of 1841, and another flood destroyed a second, similar bridge at this site in 1903.

From Wood to Steel

This led to the construction of a steel, pin-connected Pratt truss bridge in 1904, the New Hope-Lambertville Bridge. Lewis F. Shoemaker and Company of Pottstown, Pa., built the bridge, listing R.G. Devlin as the engineer. The cost: $63,818.81.

Today, the bridge carries 14,000 vehicles across the Delaware River daily; roughly the same number of pedestrians cross the bridge on a single summer weekend day. No other bridge across the Delaware sees this level of foot traffic. Tourists, residents, antique shoppers, bikers and others use the crossing to take advantage of the many attractions offered by the two communities on opposite banks.

The six-span bridge contains 962 tons of steel. Each nine-panel span measures 171 ft, and the bridge has a total length of about 1,050 ft and a roadway width of 20.3 ft. Vertical truss members measure 27 ft in height,

STEEL CENTURIONS
SPANNING 100 YEARS

Our nation's rich past was built on immovable determination and innovation that found a highly visible expression in the construction of steel bridges. The Steel Centurions series offers a testament to notable accomplishments of prior generations and celebrates the durability and strength of steel by showcasing bridges more than 100 years old that are still in service today.

The New Hope-Lambertville Bridge opened in 1904 and currently carries 14,000 vehicles across the Delaware River daily. Each of the bridge's six spans measures 171 ft, and the total length is about 1,050 ft.Vertical truss members measure 27 ft in height, and abutments date back to the original 1814 bridge.

and abutments date back to the original 1814 bridge. Pedestrians cross on a cantilevered walkway along its southern downstream side. Additionally, the bridge carries a pumped 8-in. sewer line to a treatment plant located in Lambertville.

For its first 15 years, tolls supported the bridge's operation and maintenance, but now tolls on other bridges across the Delaware support these activities, along with security. (The Delaware River Joint Toll Bridge Commission, created in 1934, owns and operates the bridge; the commission operates 20 Delaware River bridges in all.) The bridge carried U.S. Route 202 over the Delaware River until 1971, when the route was realigned to cross the river upstream on a new bridge; it now carries Route 179.

Surviving the Flood

The flood of August 1955—the greatest the Delaware River had ever experienced—destroyed many of the structures crossing it. The New Hope-Lambertville Bridge was one of the rare survivors, though its No. 2 span was seriously damaged, forcing a closure for five weeks. In 2004, the bridge underwent an extensive $7.7 million rehabilitation project, coinciding with its 100th anniversary. This figure included preliminary and final design, public involvement, construction and oversight. It also funded a free shuttle service for pedestrians, which operated when the project closed the bridge to traffic on weekdays. On weekends, construction stopped and the bridge reopened to minimize economic impact to the two connected communities.

The centennial project replaced flooring systems, sidewalk and handrails. The walkway was widened from 6 ft to 8 ft and paneled with fiberglass. Other improvements included miscellaneous steel repairs, blast-cleaning, sewer line rehabilitation and modifications to safety and lighting. Painting crews added three coats of "bridge green" anticorrosive poly-

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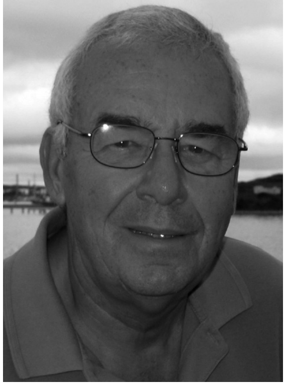

In 2004, the bridge underwent an extensive $7.7 million rehabilitation project, coinciding with its 100th anniversary.

urethane paint. The general contractor, J.D. Eckman, Inc., faced with a $10,000 per day reward or penalty, completed the project a week ahead of schedule.

As part of its security system, nine cameras on the bridge now feed images to the commission's command center. Threats of flood damage in 2005 and 2006 motivated the commission to install a radar-based level sensor to the side of the bridge that measures the river's height every 15 minutes and transmits the data via satellite to the National Weather Service and other entities. Biannual maintenance activity includes sending divers underwater to inspect for defects, cracks and scaling on the bridge's supports.

This past D-Day anniversary (June 6), maintenance crews hung banners at both ends to commemorate 200 years of bridge crossings over the Delaware River. The banners had images of the steel truss bridge as it appears today and the wooden bridge destroyed in the great flood of 1903. In addition, a film covering the bridge's history premiered in April: *The New Hope-Lambertville Bridge, Connecting Two Towns, Spanning Two Centuries*. ■

The six-span bridge contains 962 tons of steel.

Thoughts on adjusting your sales approach toward prospective clients with short attention spans.

business issues

I'M SORRY... YOU WERE SAYING?

BY ANNE SCARLETT

RECENTLY, MY firm received a query from a "hot prospect" through our website. Based on a series of initial conversations, I deduced that the prospect had a notably short attention span.

According to *Archives of General Psychiatry* and the WebMD article "ADHD in the Workplace" (by Laura J. Martin, MD), 4.4% of working adults have been formally diagnosed with ADHD, which accounts for an estimated 10-12 million professionals in the American workplace. I'm not a physician and I'm certainly not diagnosing this prospect with ADHD, but merely stressing the point that short attention spans of varying degrees abound.

At any rate, in crafting my sales strategy, it made sense to adjust my approach in order to best accommodate this prospect. I decided to research adult ADHD-like symptoms. My goal was to formulate best practices around selling (and relationship building) toward professionals fitting this profile.

After conducting my research, I concluded that there was an opportunity to modify my "typical" selling approach. After all, savvy sales professionals aim to make their client look good (and feel good) in their professional role. So, I made some adjustments, with the intention of both maximizing their positive skill sets and assisting in areas they might find challenging.

The first step is to leverage the potential strengths often found in professionals who exhibit ADHD-like behaviors—or at the very least, short attention spans. Those behaviors include the following:

Creative: People with ADHD-like behavior often propose ideas that may or may not seem relevant. To handle that, prepare a mini "parking lot" during the meeting. At the onset of your meeting, walk the prospect through your proposed agenda (you do prepare a meeting agenda, don't you?) to confirm agreement. Then, let the prospect know that you'll set aside a blank piece of paper for recording any "ideas or topics worthy of exploration at a different time." This tactic is very useful in group meetings and can also help capture spin-off ideas, thoughts and comments. Later, one attendee takes responsibility for determining (or delegating) next steps for each.

In short: Explain and use the parking lot practice with applicable clients to record extraneous ideas.

Talkative/communicative: A forthright person is a sales person's dream, right? Indeed, this behavior may enable you to learn about the prospect's goals and challenges with minimal probing efforts. That said, you may need to maintain meeting focus on the intended topics by succinctly summarizing them (even parroting back their words) throughout the entire conversation.

In short: Offer mini oral summaries as you move forward in the meeting.

Curious: Perhaps one of the most beautiful things about someone with ADHD symptoms is their innate sense of curiosity. They may ask something like "How can this be done better?" If you are new to the prospect, then the "What's better?" attitude can work in your favor, and you will follow your personal approach toward demonstrating value and differentiating your services.

If you are an incumbent but looking to grow your business with an existing client who exhibits these behaviors, then you must realize this question may be top-of-mind for your client. How might you nip their "feeling" in the bud by either a) brainstorming together about how to handle a future project or b) walking them through the post-project outcomes to demonstrate that it was done well? How might you underscore that your firm remains the best fit for their needs?

In short: Remain acutely aware of the "What's the next big thing?" or "What's better?" questions. Proactively address it during conversations with the prospect or client.

On the flip side, be aware of potential challenges that professionals with symptoms of ADHD face. Do your best to help them overcome them during your sales process and beyond. Some of those challenges include:

Short attention span: As you always do while selling, take good care to engage with enthusiasm, energy and warmth. Don't muddle your message with detail. Keep everything concise and be ready to switch on a dime if their eyes glaze over or they seem restless. When offering something new, highly stimulating or intriguing, then you may be able to capture—and hold—their attention. Continually ask yourself if there's a

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way you can reshape your message so that it feels exciting and new to them.

In short: Deliver with energy, omit the details and emphasize what's "new."

Difficulty staying on track and sticking to time commitments: If you want to make sure the meeting starts on time, make it easy by going to them. Meet in their offices, if possible. Once you've launched the meeting, try visibly checking off items on the agenda as you go through them. This will give everyone a sense of progress and accomplishment throughout the meeting.

In short: Give the overall sense that things are moving along.

Fidgety, often wants to move around: Business developers within the AEC industry love when a prospect wants to experience our projects first-hand through a site visit. This might be just the type of person who would be willing to trek to the site for a tour. (Ideally, you will provide transport.) Try offering this early in your sales cycle.

In short: Arrange a site visit, suggest a walk-and-talk after your meetings or take a "stretch our legs" coffee break.

Don't muddle your message with detail. Keep everything concise and be ready to switch on a dime if their eyes glaze over or they seem restless.

Frustrated with their lack of focus: It can be maddening for an adult to strive for career success while tackling their ADHD symptoms. Whenever possible during your sales process, try to subtly demonstrate empathy. Examples might be "Wouldn't you know it? I completely spaced out at a meeting I had last week." Or "Boy, I sure am having trouble getting through my action items list for this project." Whatever you can (honestly) share about yourself that gives them the sense that they are not alone will be appreciated. After all, many of us experience these symptoms. (A personal example: It took me a long time to write this piece; I have acquiesced to many distractions).

In short: Relate to them by sharing your own relevant challenges.

Experience challenges when reviewing detailed written work: Streamline any written documentation, and present content in bullet format. Tighten the language in your fee proposals and, if at all possible, orally walk through them through the proposal.

In short: Keep. It. Short.

Disorganized: Since these folks are often "organizationally challenged," make sure any experiences they have with you appear well organized. Ideally, they will associate you with organization.

To do this in a sales meeting, start off by helping them get organized by providing a brief list of what they should bring to the meeting. This can be done in your email confirmation. Perhaps they need to bring a calendar, business cards, other colleagues, specific documentation about their potential project, budget numbers, etc. Also, be very organized yourself when you are conducting the meeting. Present your materials in an even more organized manner than you might otherwise. (One example: Put materials about their project in a three-ring binder with labeled tabs. This radiates a level of competency, and a "we can handle this for you" spirit.)

In short: Demonstrate your own über-organized skills.

Procrastinate: As with any prospective client, you always want to agree upon a "next step." In these cases, you may want to reiterate scheduled steps/commitments more than once (i.e., orally during the meeting, recap at the close of the meeting and in a follow-up email). Also, try to keep the next steps as close together as possible. While this is certainly a goal in every sales process, there might be ways to shave off a day here or a day there to help the procrastinator to feel the sense of urgency that he/she might actually thrive within.

In short: Strive to keep the process tight.

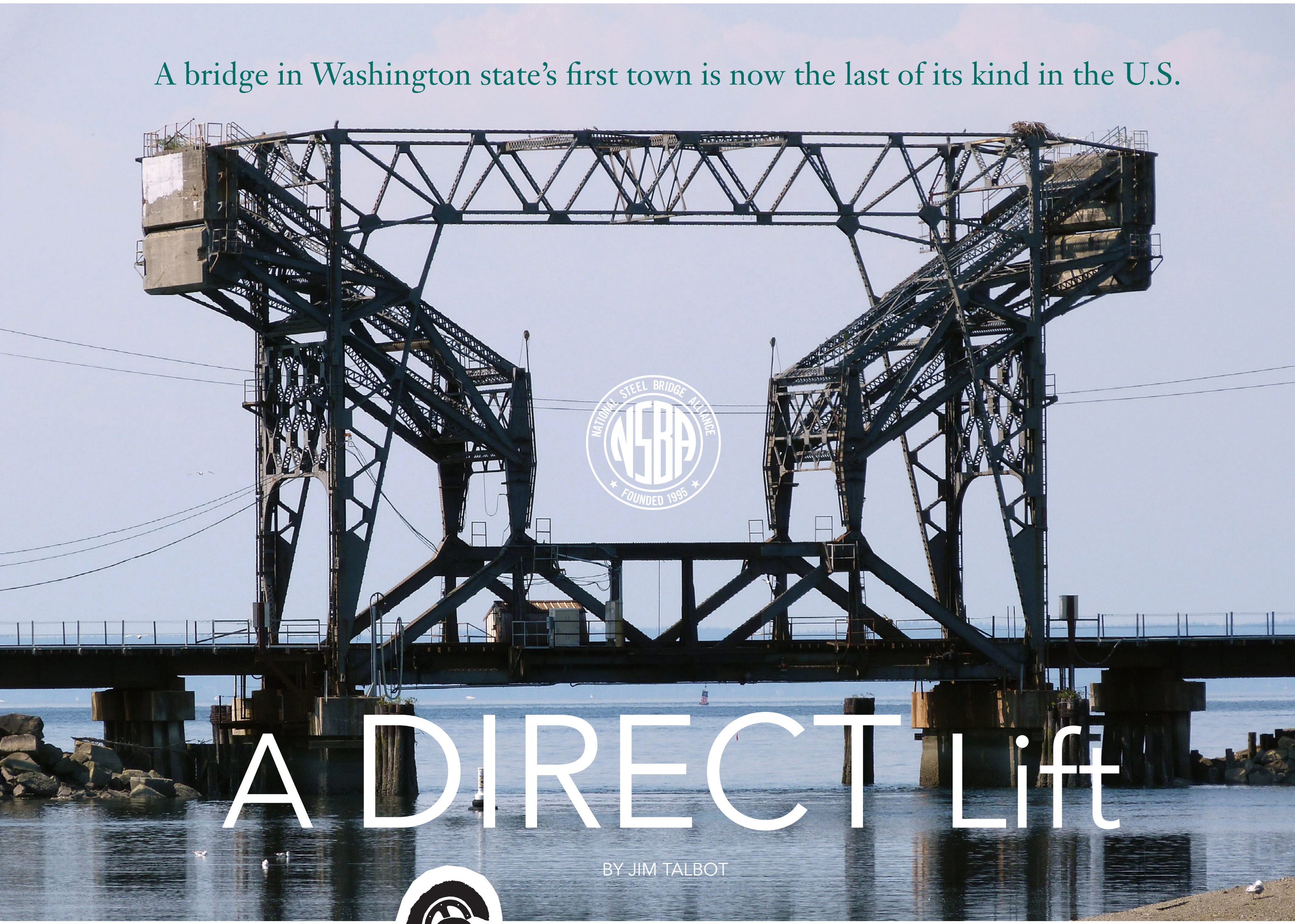
Express emotion that may seem intense, short-fused or irrational for the workplace. Help guide them back to a rational, calm and professional state of mind (but try not to squelch any positive passion or personal investment). Suggest win-win alternatives whenever possible. If the discussion is going south with no signs of immediate recovery, then propose a break for 15 minutes before reconvening. This might be more likely to happen if you are up-selling to an existing client rather than working through the sales process with a prospective client.

In short: Aim for win-win; demonstrate a calm, professional demeanor; suggest a break.

These are the adjustments that I've used with the prospective client I mentioned earlier. So far, I have managed to get to know her better through a series of fairly successful "touches." I feel optimistic about turning her company into a client.

To reiterate, I am a complete novice when it comes to adult ADHD. If any of you readers have advice and comments from your experiences in similar situations, I would enthusiastically welcome your feedback.

A bridge in Washington state's first town is now the last of its kind in the U.S.



A DIRECT Lift

BY JIM TALBOT

STEEL CENTURIONS
SPANNING 100 YEARS

Our nation's rich past was built on immovable determination and innovation that found a highly visible expression in the construction of steel bridges. The Steel Centurions series offers a testament to notable accomplishments of prior generations and celebrates the durability and strength of steel by showcasing bridges more than 100 years old that are still in service today.

Images: Nathan Holth/HistoricBridges.org

IN 1854, STEILACOOM BECAME the first incorporated town in what is now Washington state.

At the turn of the century, with the approach of the Northern Pacific Railway, the town leaders hoped Steilacoom would become its western terminus. But the railroad just wanted a water-level route along Puget Sound on its way south past Tacoma, so it bought up rights through Steilacoom and continued south toward Olympia. In doing so, it had to cross Chamber's Creek, which emptied into Puget Sound in northern Steilacoom.

The U.S. Corps of Army Engineers considered the creek a navigable waterway, which dictated a movable bridge. The railroad contacted the Strauss Bascule Bridge Co. in Chicago, engineers and designers of trunnion, bascule and lift bridges. Joseph B. Strauss, America's premier bridge designer at the time, proposed and patented a radical new structure type—what has become known as the Strauss vertical direct-lift bridge.

The bridge depends not on tall towers and cables to lift the 97-ft movable bridge section, but rather on a direct rack-and-pinion arrangement. (Apparently Strauss wanted to avoid the inevitable stretching of cables under load, which would require adjustment and rail traffic interruptions.)

Two other vertical direct-lift bridges of similar design (though not Strauss') have been built in the U.S.—one across the Illinois River in Illinois and the other across the Ohio River in Kentucky. But the bridge across Chamber's Creek, built in 1914, is currently the only such bridge remaining in the U.S. (A Strauss direct-lift rail bridge, also built in 1914, crosses the Fraser River in British Columbia, Canada.)

◄▼ The Chamber's Bay Bridge is the last of its kind still standing in the U.S.

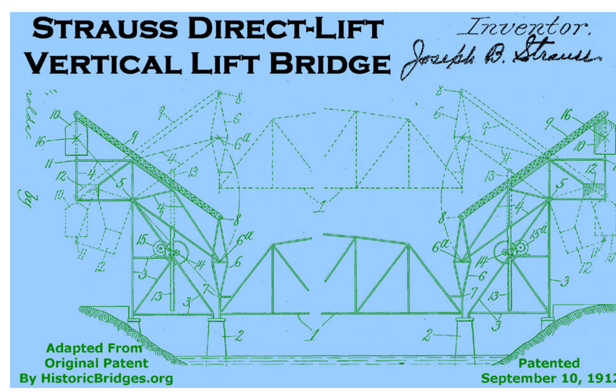
▲ Steel trusses mounted on the tower posts on either side of the movable span support concrete counterweights.

▼ A diagram of the Strauss vertical direct-lift bridge.

According to the Historic American Engineering Record (HAER) for this bridge (which goes by several names, including the Chamber's Bay Bridge, Bridge 14 and the West Tacoma Bridge) steel trusses mounted on the tower posts on either side of the movable span support concrete counterweights. A system of counterweights, trusses, hangers and links forms a jointed frame in the shape of a parallelogram. Reportedly, the parallelogram has proportions so as to be in perfect equilibrium in all positions. The lift span, a pony truss, carries two rail tracks.

The HAER record states that each tower post contains a vertical rack that engages corresponding spur gears on the lift span. At each end of the bridge, 25-hp motors connect to the pinions in such a way that the four span corners always move together. The operator resides in a cabin mounted on the lift span and in case of a power failure, he can manually lift the span. The maximum vertical lift of the bridge is 43.5 ft, and the bridge mechanism was designed to lift a weight of 15 tons.

Information in an early *Engineering News-Record* article about the Strauss design noted that direct-lift bridges with double-balance levers are practicable and economical only for small lifts. Today, the structure is designated Bridge 14 of the BNSF Railway, which represents the result of more than 390 merged railroad lines. According to a BNSF publication, the average weight of a rail car was 40 tons and the average length of a train 50 cars in 1914. Now the average car weighs 142 tons with an average train length of 100 cars.



Years of increased tonnage from rail traffic eventually caused the bridge's seats to founder. In 2004, BNSF refurbished the bridge, replacing its seats, saddles, cover plates, some steel work and the rail tracks. During reconstruction, trains crossing the bridge span had to travel at 10 mph or less and several closures were necessary. The reconstruction project has allowed the BNSF railway's historic bridge to continue to operate for many years to come. ■

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