Reprinted from 2012 MSC

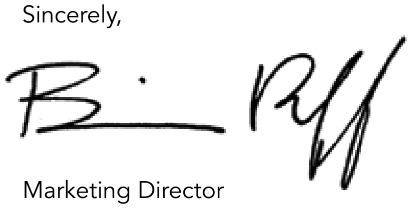
Steel Bridges 2012

Welcome to Steel Bridges 2012!

This publication contains all bridge related information collected from *Modern Steel Construction* magazine in 2012. These articles have been combined into one organized document for our readership to access quickly and easily. Within this publication, readers will find information about Steel Centurions, aesthetics, and rapid replacement among many other interesting topics. Readers may also download any and all of these articles (free of charge) in electronic format by visiting **www.modernsteel.org**.

The National Steel Bridge Alliance is dedicated to advancing the state-of-the-art of steel bridge design and construction. We are a unified industry organization of businesses and agencies interested in the development, promotion, and construction of cost-effective steel bridges and we look forward to working with all of you in 2013.

Sincerely,



Marketing Director
National Steel Bridge Alliance

Table of Contents

Back on the Job

BY JIM TALBOT

Laser scanning sped the rehabilitation and third deployment of this historic iron and steel bridge.

BRIDGE 5721 IN MINNESOTA recently got its third lease on life. After a high-tech diagnostic survey followed by dismantlement and a thorough refurbishing, the structure, which is now officially identified as Bridge 82524, was reassembled in early 2011, then lifted into place in its third location. This is the second time this early metal bridge, originally constructed sometime in the 1870s, has been dismantled and reconstructed in a new location to serve the changing needs of the area.

The original wrought-iron truss bridge originally carried equestrians and those on foot on Main Street over a river in Sauk Centre, Minn. The hometown of writer Sinclair Lewis, Sauk Centre also served as the model for Lewis' satirical 1920 novel *Main Street*. In 1937 the bridge was disassembled and moved north to Koochiching County to carry vehicular traffic on State Road 65 over the Little Fork River near Silverdale. In 2009 it was again dismantled for refurbishment and moved south for reassembly.

In October of 2011, reincarnated as Bridge 82524, it came full circle. Although still known by many as the Silverdale Bridge, the bridge is now owned by the Minnesota Department of Natural Resources and carries horses and riders on the Gateway Trail over Manning Avenue near Stillwater, Minn.

This structure is one of 24 historic bridges designated for long-term preservation by the Minnesota Department of Transportation (MnDOT). In carrying out preservation projects on this set of bridges, engineers must collaborate with historians. The collaboration process is intended to preserve the bridge's "character-defining features" and to conserve as much of the historic fabric of the bridge as possible. However, replacement bridge parts may be used to satisfy safety, performance and practicality concerns, especially for minor features that improve overall life expectancy.

Structurally, Bridge 82524 is a single-span, 162-ft Parker through-truss with pinned connections. Each side of the truss is composed of eight panels, and together they support a 17-ft-

◄ ▲ Finished Bridge 82524 at its new site on the Gateway Trail near Stillwater, Minn.

▼ Bridge 5721 in its original location, Main Street of Sauk Centre, Minn., circa 1920.

▼ Bridge 5721 at its second location, near Silverdale, Minn., where it remained until 2009.

wide deck. The Parker truss is characterized by vertical members, diagonals and a "camelback" shape with sloped upper chords. Being a variation of a Pratt truss, the major diagonals on both sides of the bridge slope down toward the center vertical.

Although with the emergence of the U.S. steel industry steel would by the 1890s become the material of choice for metal bridges, the original Sauk Centre bridge was built with wrought iron, which was typical for 1870s bridge construction. Its primary truss components include eyebars and sections built up using riveted angle and plate components. Paired, punched eyebars serve as the major diagonals and bottom chords. All vertical members are double paired-angle sections with V-lacing. V-lacing also graces the top and bottom of the upper chord channels. Top and bottom crossed rods with turnbuckles provide lateral bracing. For the flooring system, built-up wrought iron floor beams support rolled steel stringers. At the Silverdale site a timber plank deck was used. At its new home on the Gateway Trail, a lightweight concrete deck is supported by new steel stringers.

Appearance Counts

Ornamental touches, which are relatively rare, greatly contribute to the aesthetics of this bridge. The overhead bracing members and their plates are perforated with circles and crosses. Overhead sway bracing consists of four angles with X-lacing and knee braces. The sway bracing also contains ornamental plates, each punched with four circles and a cross. Portal bracing is a lattice of angle sections.

Jim Talbot is a freelance technical writer living in Ambler, Pa.

▲ Workers disassemble Bridge 5721 in 2009 at the Silverdale site.

▲ In the spring of 2011 crews reassembled the truss on the ground near its new location, after which it was trucked into position for hoisting into place.

Laser Scanning

Lack of original design drawings creates a challenge for the rehabilitation of any century-old bridge, and predictably no 1870s plans were available for Bridge 5721. To obtain the baseline data needed to evaluate the bridge and engineer its rehabilitation, surveyors for MnDOT scanned the bridge with a Leica laser scanner prior to disassembly. "Laser scanning dramatically cut the amount of field time required to collect geometric data for the rehabilitation project," said Steve Olson, president of Olson & Nesvold Engineers (O.N.E.) "It also permitted the quick collection of a great deal more information than using conventional surveying methods."

The 3D laser scanner collects data by firing a laser 50,000 or more times per second and monitoring the reflections. The equipment can concurrently take associated photographs of structures. To assemble the scan data for the full bridge, MnDOT surveyors set up the scanner in nine different locations prior to disassembly of the structure. After two and a half days of scanning, they used software to stitch together the data to create a registered "point cloud" consisting of 13 million points, each with x, y and z coordinates.

A point cloud is a geometrically correct digital representation of the bridge that can be viewed from any angle. This detailed representation of the bridge can be readily used for engineering work, as well as for historical records.

Olson points out the point cloud models can be viewed using a variety of software. "It is a great tool to have while working on historic bridge or structural rehabilitation projects," Olson said. "You can slice and dice a point cloud model to get just about any bit of geometric information imaginable."

In addition, crews scanned each major truss member as it was removed to provide information on the fastener patterns. Those operations took place on a scanning table before the pieces were loaded onto a truck and moved to the storage site.

Replacement and Rehabilitation

The latest rehabilitation required replacement of only two of the nine floor beams, specifically the beams at each end. "The data from the laser scans data was used to develop detailed drawings which were then used by the fabricator to make the new floor beams that fit the original connections," Olson said. "We also replaced the roller nest bearings with elastomeric bearings."

Today the bridge has a completely new floor system, from the stringers up. "At the Silverdale site, the roads on both ends drained toward the bridge," Olson said. "Drainage through the timber deck caused the paint system on the steel stringers to fail. As a result, all 10 steel stringers added in 1937 and bolted to the top of the floor beam flanges had extensive corrosion and

▼ Portal bracing is a lattice of angle sections.

▼ Overhead sway bracing consists of four angles with X-lacing and knee braces. The sway bracing also contains ornamental plates, each punched with four circles and a cross.


Steve Olson

In May 2011 two cranes lifted the truss and set it on its new abutments on the Gateway Trail.


Tim Davis/HNTB

At the bridge's new home on the Gateway Trail, a lightweight concrete deck is supported by new steel stringers.

required replacement. Additionally, a lightweight concrete deck replaces the original timber deck to minimize the dead load."

The use of lightweight concrete for bridge decks in Minnesota is rare. However, a conventional concrete deck would have weighed enough to require that several truss members be strengthened with additional steel components. Because adding components would have altered the look of the bridge members and detracted from their historic character, the lightweight option was selected.

Photos taken in the early 1900s show that the original portals differ from the 2009 configuration. The project historians decided to more closely match the earlier configuration by going back to portals with lower clearance. "Laser scanned data of the fastener patterns of the existing portals helped us to detail replacement portals and return the portal clearance back to 14 ft from 16 ft," Olson said.

The contractor removed the old lead-based paint on the reused components and applied a new four-coat paint system recommended by coatings consultant KTA-Tator, Pittsburgh, and based on the three-part system that is standard for steel bridges. "We were worried about corrosion in the crevices between the lacing and other components," Olson said. "The recommended fourth component is a penetrating sealer installed between the primer and mid-coat."

In the spring of 2011 crews reassembled the truss on the ground near its new location. In May two cranes lifted the truss and set it on its new abutments on the Gateway Trail. Final touches included installing the deck, painting and adding the equestrian railing. And with that kind of preparation, perhaps it can last another 135 years.

Original Owner
Minnesota Department of Transportation

New Owner
Minnesota Department of Natural Resources

Structural Engineers
(Disassembly and Rehabilitation Design)
HNTB, Minneapolis, Minn., and Olson & Nesvold Engineers (O.N.E.), Bloomington, Minn.

Steel Fabricator
White Oak Metals, Dalton, Minn. (NSBA/AISC Member)

General Contractor
Minnowa Construction, Harmony, Minn.

Two and a half days of laser scanning, plus some time to process the data, produced a registered "point cloud" image of the bridge consisting of 13 million points, each with x, y and z coordinates.


O.N.E.

A replacement floor beam for each end of the bridge was fabricated using data from the laser scanning process; the roller nest bearings also were replaced with elastomeric bearings.


Tim Davis/HNTB

Final touches included installing the deck, painting, and adding the equestrian railing.


Tim Davis/HNTB

3D Laser Scanning in 2012

Over the last three years the construction market has undergone a complete transformation in the way as-built information is collected. Laser scanning technology has been a driving force behind this change and already has found its way into many projects around the word. Considering how rapidly the premier software providers have adapted to this technology as a data source, especially for BIM-based design software, the expanded use and importance of laser scanning will continue to grow.

Design and construction professionals looking to use this technology should begin their research by looking at the intended application. At this time there is no all-in-one 3D laser scanner, so you must do your research and find the unit that best fits the needs of your company. Below are five points you must address before deciding on a scanner, regardless of your role on the building team.

1. Application – Civil Survey, Build Construction, Exterior, Interior
2. Operation – Internal Survey Crew, Project Managers, Virtual Design and Construction Department
3. Design Team – Internal Registration, Internal Modeling, Outsourcing All Post-Processing
4. Data Flow – Design Software, Clash Detection, Field Management Software
5. Data Transfer – Cloud, External Hard Drives, Handling Data File Size (1GB plus)

To understand how job-specific project details figure in the selection of particular scanning capabilities, consider the example of an adaptive reuse or renovation construction projects. For AEC personnel working this type of project, creating an accurate model of existing building conditions is critical to understanding the current structure and spatial utilization of a building. Only a few options satisfy those needs while also accommodating the contractor with speed, safety and ease of use. One option would be to use an advanced 3D laser measurement instrument, like the Trimble CX 3D laser scanner, which is designed to help building contractors solve this very problem.

Laser scanning is a very good tool to use in the following applications:

- Capturing existing condition data for accurate adaptive reuse and renovation construction planning and design.
- Comparing the existing structure against the planned design to identify "clashes" prior to construction.
- Verifying the "flatness" of the existing floors to determine if improvements are needed before reuse construction or renovation begins.
- Ensuring pre-fabricated parts will fit in their intended location prior to transportation and installation on the project.
- Creating as-built construction drawings for quality assurance purposes.
- Creating a 3D model of the complete facility for daily operation planning and analysis by building owners.

Total Solutions

Although the companies offering laser scanning technology all support data exchange, to varying degrees, the best solution most often is to use an integrated system. Our firm uses the Trimble line of products. We have found that with the intuitive, streamlined Trimble Access software running on the Trimble Tablet Rugged PC, capturing data with the Trimble CX 3D laser scanner is fast and easy to learn. Data can then be seamlessly transferred to Trimble RealWorks survey software. Once there, the point cloud can easily be manipulated and data exported to the detailing package of choice.

Laser scanning systems are not inexpensive, with a baseline complete package starting at about $60,000. However, our clients have realized significant reductions in the unit cost of data acquisition. With technology that maintains high accuracy over an extended operating range, we capture 54,000 points per second using a typical field setup. A survey that would have taken a full day for a two-person crew just three years ago now can be done by a single person in a matter of hours. It also yields a data package that is greater in quantity by several orders of magnitude, and also virtually error free. The limiting factor today has gone from being data acquisition to data manipulation and use.

—Information provided by Nick Dibitetto, Building Construction Division Manager, Precision Midwest, Warrenville, Ill. MSC

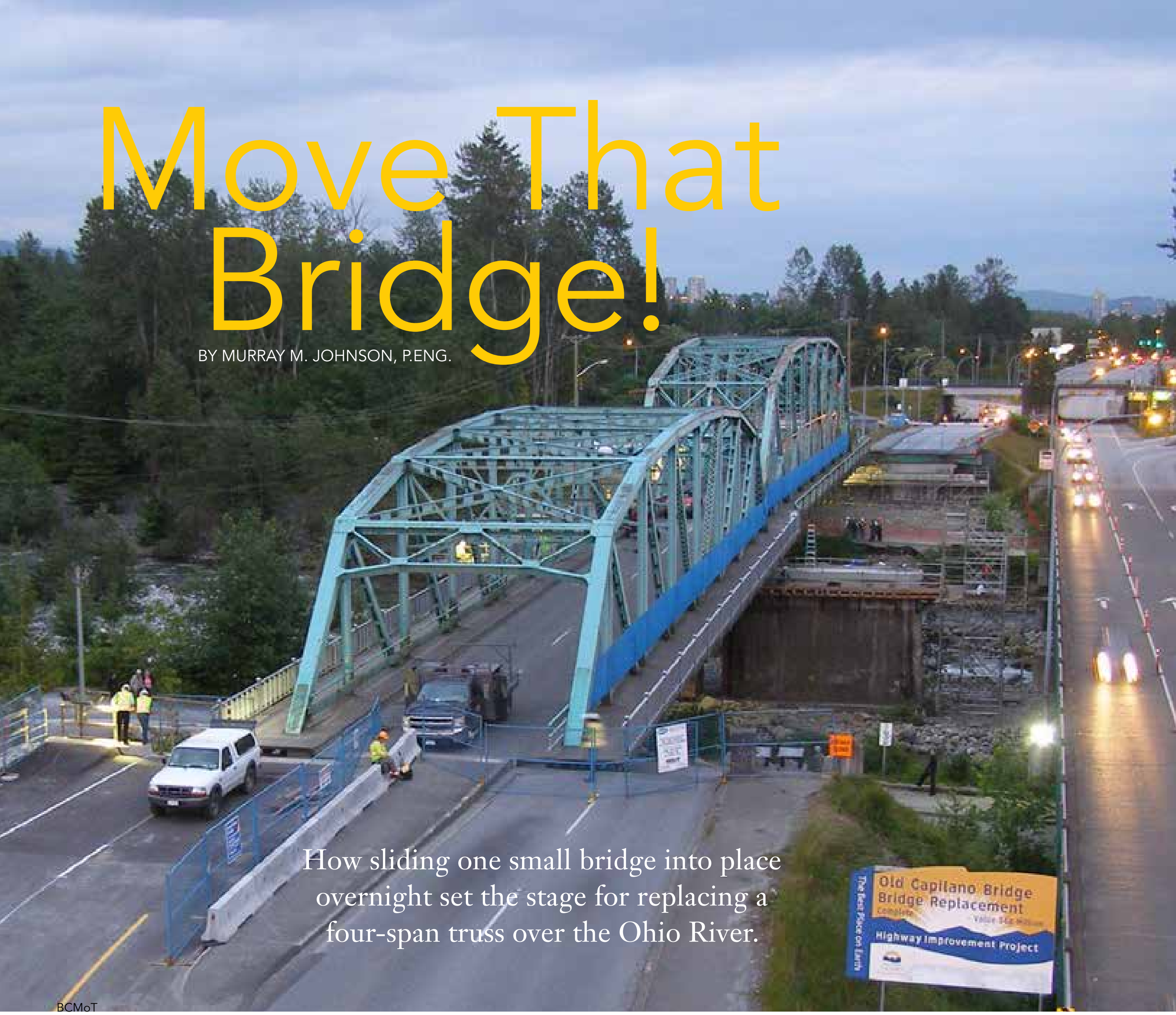
Looking very much like a standard surveying instrument, a laser scanner such as this collects huge amounts of data rapidly and accurately.


Trimble Navigation

Move That Bridge!

BY MURRAY M. JOHNSON, P.ENG.

How sliding one small bridge into place overnight set the stage for replacing a four-span truss over the Ohio River.



BCMoT

▲ The Old Capilano River Bridge halfway through the sliding operation (moving right to left in photo). Note one lane of westbound traffic being accommodated on normally eastbound bridge at far right.

REPLACING A VITAL BRIDGE carrying busy traffic loads over water, with limited or onerous alternate routes, is a serious undertaking. It generally requires either a new alignment, some form of staged construction that maintains partial traffic while the bridge is replaced around it, or construction of a temporary detour bridge. Existing road connections, built-up urban areas, other infrastructure, right-of-way limitations, or other site constraints often preclude a new alignment. Staged construction usually disrupts traffic and is always more expensive than building the new bridge in one pass, and not even structurally feasible for some bridge types. Sometimes a detour bridge may be built with a lesser length or to a lower standard, such as over a seasonally variable watercourse, but often the scale of the detour bridge required matches that of the permanent bridge itself. This can dramatically increase the project cost and delay or even prevent an owner from proceeding with it due to funding limitations.

One innovative technique for providing the detour for a bridge replacement, while keeping the original alignment, involves using either the old bridge or the new superstructure as the detour and

Murray Johnson, P.Eng., is an executive engineer with Buckland & Taylor Ltd., North Vancouver, British Columbia, specializing in bridge construction engineering. He can be reached at **mmj@b-t.com**.

BCMoT

The Old Capilano River Bridge during sliding, with bridge halfway from old river pier onto temporary pier. A one-minute time lapse video of the slide is available on YouTube at **http://bit.ly/zT6dZ5**.

employing lateral sliding of the superstructure during construction to reposition it during a short closure. Lateral sliding of bridge superstructures has been used as a construction technique on smaller girder bridges such as highway overpasses, but is less common on larger spans.

In June 2010, the 80-year-old Capilano River Bridge, in West Vancouver, British Columbia, was slid sideways onto a temporary pier and abutments during an overnight closure and reopened to traffic in the morning, becoming an instant, low-cost detour while a replacement bridge was built in the original location. Near the end of 2012, the new Milton Madison Bridge, spanning the Ohio River between Kentucky and Indiana, will be closed for just a few days while it is slid sideways, from the temporary piers upon which it is being constructed onto rehabilitated and enlarged original piers, after serving as the traffic detour while the old bridge superstructure is demolished.

In both cases, the sliding technique allows the projects to be built while minimizing disruption to traffic, accelerating construction, and reducing costs considerably. The difference is one of magnitude: The two-span, 430-ft, 1,280-ton Capilano River Bridge slide will be scaled up dramatically at Milton Madison, where four steel truss spans measuring 2,430 ft and weighing 15,260 tons will be slid into place.

Murray Johnson

Workers monitor progress, keeping a close eye on tight clearances, as the Old Capilano River Bridge slide continues.

The Capilano River Bridge

The Capilano River Bridge carries all westbound traffic on Marine Drive from North Vancouver and off the iconic Lions Gate Bridge from Vancouver, over the environmentally-sensitive Capilano River. Originally built in 1929 as a single 250-ft steel truss span with short jump spans at each end, a second 180-ft steel truss was added after a 1949 flood washed out the west bank, abutment and jump span and widened the river.

By 2009, the two shoulderless narrow lanes of the bridge were a bottleneck for the more than 25,000 vehicles using it each day. Pedestrian and cyclist accommodation was poor, transit improvements were needed, and the bridge was deemed to be functionally obsolete. The bridge owner, the British Columbia Ministry of Transportation and Infrastructure (BCMoT), had longer-term plans for replacement of the bridge when funding help was suddenly offered under the Canadian federal government's infrastructure stimulus program.

Murray Johnson

Truss sliding runway at the Old Capilano River Bridge piers during the sliding operation.

The Old Capilano River Bridge in operation as the detour while new bridge substructures start to take shape. Wood hoardings at both ends of site accommodated pedestrian traffic through the bridge site throughout construction.

BCMoT


BCMoT

New steel girders being launched from the Capilano River's east bank, over the river pier and closing in on west abutment.


Murray Johnson

The completed New Capilano River Bridge.

The catch: in order to receive the funding, project completion was required in less than two years, including design and construction. This tight deadline was further complicated by additional schedule constraints related to the upcoming Winter Olympics, during which roadwork was banned, and very limited in-stream working windows due to the salmon-bearing values of the river.

The BCMoT dove into planning for the project. With the help of a study by Buckland & Taylor Ltd. (B&T), international bridge engineers headquartered in North Vancouver, British Columbia, the solution chosen was to slide the old bridge superstructure upstream onto temporary supports to become the construction detour, thereby exposing the original alignment for demolition of the old abutments and pier and construction of a new, wider bridge. Less than three months from the conception of the project, construction of detour approaches was well under way and tenders had been called for building a temporary pier.

Two months later, in September of 2009, the temporary pier had been finished within the short "fish window" period, and left for the main contractor to slide the bridge onto in 2010. This pier, which would be the sliding runway as well as support the bridge in temporary service, used a forest of steel pipe piles drilled into the river bed, topped by steel W-shape cross-caps and a heavily reinforced concrete cap/sliding beam which was directly connected to the old concrete pier.

Design of the new bridge continued through the winter while the temporary approaches, using modular concrete blocks and geogrid-reinforced fills, were completed. A construction contract was awarded and sitework began on April 1, after the Olympics shutdown.

Schedule again was a factor, as the old bridge had to be slid out of the way in time to allow in-stream work on the new bridge to take place during the summer "fish window." To speed the process, the required design for the sliding was included in the tender documents with only details, equipment and work procedures to be added by the contractor.

Moving Old Trusses

The old steel trusses were supported on pinned shoes at each bearing location, some fixed, some on steel roller nests. After installing steel sliding tracks along each runway, the trusses were jacked up during short night closures and sliding shoes—steel plates with PFTE pads—inserted under each bearing. Old rollers were removed and replaced with stacks of steel plates. Although the two truss spans were structurally independent, the 1949 truss shoehorned onto the pier around the existing 1929 truss. That meant the bearings at the pier were nested and had to be dealt with together, and a common sliding shoe was inserted here.

The bridge was rotated in plan as it was slid, to suit the required alignment of the detour, so a different pulling speed was required at each of the three support lines. Moving the bridge was done using pairs of hydraulic jacks pulling on high-strength threaded bars, cycling up to 6 in. at a time.

The sliding design eliminated vertical jacking requirements at the conclusion of the slide, saving money and especially time. The detour approach roadways had been carefully positioned so that when the bridge arrived in the new location, it was vertically aligned and traffic could flow as soon as the deck joints were covered. The PTFE sliding elements that were the lateral sliding element became the longitudinal sliding bearings for the bridge in its new service.

Prior to the scheduled sliding date, a test slide was required, moving the bridge 1 in. then stopping, in order to test equipment, communications and control. After a few minor adjustments, one Saturday evening traffic on the bridge was diverted and the bridge closed for the sliding operation. The steel tracks were greased and the bridge was moved along its curved path, held on course by a single guide track at the pier, arriving in the detour location less than 6 hours later. The remainder of the night was spent installing restraints at the bearings, covering the deck joints, and repositioning roadway barriers. The bridge was reopened to traffic the following morning, with many drivers hardly aware that it had been moved. With the site now available, construction started immediately on the new bridge.

The most economical design for the new bridge was determined to be a two-span continuous steel plate girder structure with a cast-in-place composite deck and integral abutments, without deck joints. The single pier in the river and both abutments are supported on steel pipe piles. Because the profile of the roadway over the bridge includes a symmetric vertical curve with a rise of about 2 ft, by keeping the girder bottom flange horizontal the girder depth varied from 5 ft at the abutments to 7 ft over the pier, neatly accommodating the higher bending moment demands over the pier. Five steel plate girders of 50 ksi weathering steel at 12-ft spacing support a 57-ft-wide cast-in-place concrete deck carrying three lanes of traffic, shoulders and a wide shared pedestrian and cycle path. The contractor chose to launch the steel girders across the river from one bank, bolting two of the three sections together, pushing them partway out, then bolting on the remaining section in the limited site space before finishing the launch.

Kicking it Up a Notch With a Design-Build Innovation

Design-build bids were solicited for the Milton Madison Bridge replacement over the Ohio River near Madison, Ind., in June 2010. The joint owners of the bridge, the Kentucky Transportation Cabinet and the Indiana Department of Transportation, had studied the bridge replacement issue extensively with their engineers and had arrived at the concept of rehabilitating most of the existing piers and replacing the superstructure. Although the existing steel truss bridge, built in 1929, is very narrow, without shoulders or sidewalks, deteriorating, and functionally obsolete, it is the only crossing in a 72-mile stretch of the Ohio River and is vital to the communities it serves.

Bidders were to replace the entire superstructure with a new wider four-span continuous steel truss bridge with new concrete girder approach spans. Four of the five piers supporting the new main span's superstructure would be rehabilitated existing piers. The roadway and sidewalk requirements, as well as the general dimensions and some design features of the truss, were pre-established to meet the pier constraints as well as the requirements of a public consultation process for replacing the historic but deteriorated bridge. Main truss spans would be 600 ft, 600 ft, 727 ft, and 500 ft, with 48-ft center-to-center of trusses.

Bid documents included a formula to establish the effective bid price. To the contractor's construction price would be added an amount equal to $25,000 per day for every day the bridge was closed, limited to a maximum of 365 days. In addition, two completion dates, September 2012 or May 2013, were allowed, with a deduction of $3.75 million from the effective bid price for committing to the earlier date. A round-the-clock ferry would have to be operated for the closure period of the bridge.

Walsh Construction Ltd., Crown Point, Ind., teamed up with Burgess & Niple, Inc. (B&N), Columbus, Ohio, and Buckland & Taylor to bid the project. B&N would design the approaches and the pier rehabilitation while B&T would perform both the design and the construction engineering for the steel main spans. In addition to coming up with efficient designs for the new permanent structure, the challenge for the bid design team was finding an innovative solution that would eliminate the need for a long bridge closure and reduce construction risk associated with schedule.

The team developed a bold solution building on B&T's recent success with sliding the Capilano River Bridge. The existing bridge would remain open to traffic while beginning the pier rehabilitation, while the new bridge superstructure would be completely constructed alongside on temporary piers. Traffic would then be diverted onto the new structure and the old superstructure and pier tops demolished to make way for the completion of the new pier caps. Temporary access ramps for traffic would allow the new approaches to be completely built in their final position. Finally, when all was ready, the bridge would be closed for a few days at most and the entire new superstructure slid into final position.

With a bid price of $103.7 million, a bridge closure bid of only 10 days, and the earlier completion date, Walsh was the successful bidder. The design of the new steel truss bridge, a 2,430-ft continuous truss built using 8,200 tons of high-performance 50 ksi and 70 ksi steel, with a continuous concrete deck on floating bearings, is remarkable but beyond the scope of this article.

Tons of Temporary Steel

The temporary works associated with the plan are extensive and involve a total of some 3,200 tons of steel piling and fabricated steel. In accepting the concept of operating public traffic on a bridge on temporary supports, the owners required that the design criteria be essentially the same as for a permanent structure. The most significant consequence of this is related to the ship impact

➤ New Span 2 trusses for the Milton Madison Bridge being assembled on barges at Kentucky bank, shown one-third complete.

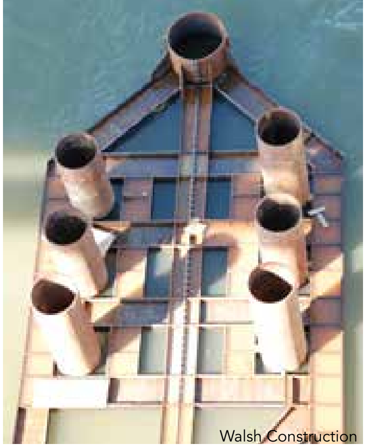
Deborah Crawford

➤ Overall view, looking from Indiana to Kentucky, of the existing Milton Madison Bridge (left). New Span 2 trusses being assembled on barges at Kentucky bank, shown halfway complete.

Murray Johnson

➤ New Span 2 trusses for the Milton Madison Bridge being assembled on barges at Kentucky bank.

Murray Johnson



Walsh Construction

◄ Welded steel barge impact frames for Temporary Pier 3 on the Milton Madison Bridge project, doubling as pile driving template.

► Welded steel box beams for the Milton Madison Bridge temporary piers.

Murray Johnson

loadings required for the temporary piers, because long trains of heavily loaded barges operate on the Ohio River. Complicating this is a highly variable water level at the bridge location. These factors result in a temporary pier design with massive steel barge impact frames at three levels, heavily connected to the strengthened permanent pier stems and protecting the six 36-in.-diameter steel pipe piles supporting the temporary towers. These will include 1,250 tons of steel in barge impact frames and temporary pier towers, as well as 1,400 tons of steel pipe piles.

The two truss spans over the main river channel are being assembled on barges against the Kentucky shoreline, and will be floated out one at a time and lifted some 80 ft into place using strand jacks. To accommodate the lifting, three of the temporary piers will have lifting towers added on top, while the end of one span will be lifted by jacks perched on top of the new truss top chord. Once lifted, the truss spans will be set on heavy steel box girders, 101-in. deep and 78-in. wide, which double as the top caps for the temporary pier supported on two levels of sub-caps and, eventually, as sliding runways. Hillsdale Fabricators, St. Louis, is producing some 520 tons of these temporary girders, using plate up to 3-in. thick as well as associated support steel.

Once the two central truss spans are lifted and secured, the side span trusses will be erected piecemeal, using cranes on barges and land, cantilevering toward the river banks. Intermediate erection bents will take the load near river's edge and jack the trusses to allow them to land on the two end temporary piers. Padgett, Inc., New Albany, Ind., is fabricating 75 tons of temporary sliding girders and pier caps for these end piers. Following completion of steel erection, the new bridge superstructure will be completed with concrete deck, sidewalk, barriers, and temporary expansion joints, and linked to the temporary approach ramps to start carrying traffic.

Sliding

The sliding will come after demolition of the old bridge superstructure and completion of the new pier caps. Similar to the Capilano River Bridge, the new bearings and the sliding process have been designed so that on completion of sliding, no vertical jacking is required. When the PTFE element built into the truss bearing for lateral sliding arrives in its final position, it will simply be fastened to the embedded bearing plate.

The sliding track at each pier will include the top flange of the temporary pier girders, the masonry plates, and sliding plates set on the pier concrete between the bearing plates. Bearings that in permanent service will be sliding bearings will be temporarily locked together for the lateral slide, and also as for Capilano, the entire structure will be guided along a path at the center pier, allowing thermal movements to occur in both directions during the course of the slide.

On sliding day, the entire superstructure will be moved 55 ft upstream to its new position, pulled by strand jacks linked to a computerized, displacement-monitoring control system. One adjacent approach span will also be separately slid into place, and then expansion joints will be completed at the bridge ends and the bridge reopened to traffic in its permanent position.

In meeting the goals of accelerating bridge replacement, providing efficient detours for unrelenting traffic, and building cost-effective new bridges, lateral sliding of bridge superstructures, longer and heavier than ever, is one more tool that designers and builders can employ. The success of the Capilano River Bridge project has helped develop the techniques that are now being used on a much larger bridge, and undoubtedly will be used on many more future bridge projects, as owners and contractors try to meet the demand for faster, more efficient, less disruptive and more sustainable construction. MSC

Capilano River Bridge

Owner
British Columbia Ministry of Transportation & Infrastructure

Structural Engineer
Buckland & Taylor Ltd., North Vancouver, British Columbia

General Contractor
Neelco Construction Inc., Chilliwack, British Columbia

Milton Madison Bridge

Owners
Indiana Department of Transportation and Kentucky Transportation Cabinet

Owner's Engineers
Michael Baker Jr., Inc., Louisville, Ky., and CDM Smith, Indianapolis

Structural Engineer (Main Spans Design and Construction)
Buckland & Taylor Ltd., North Vancouver, British Columbia

Structural Engineer (Pier Rehabilitation, Approach Spans, and Temporary Ramps)
Burgess & Niple, Inc., Columbus, Ohio

General Contractor
Walsh Construction Co., Crown Point, Ind.

Steel Detailer (New Bridge)
Tensor Engineering, Indian Harbor Beach, Fla. (AISC Member)

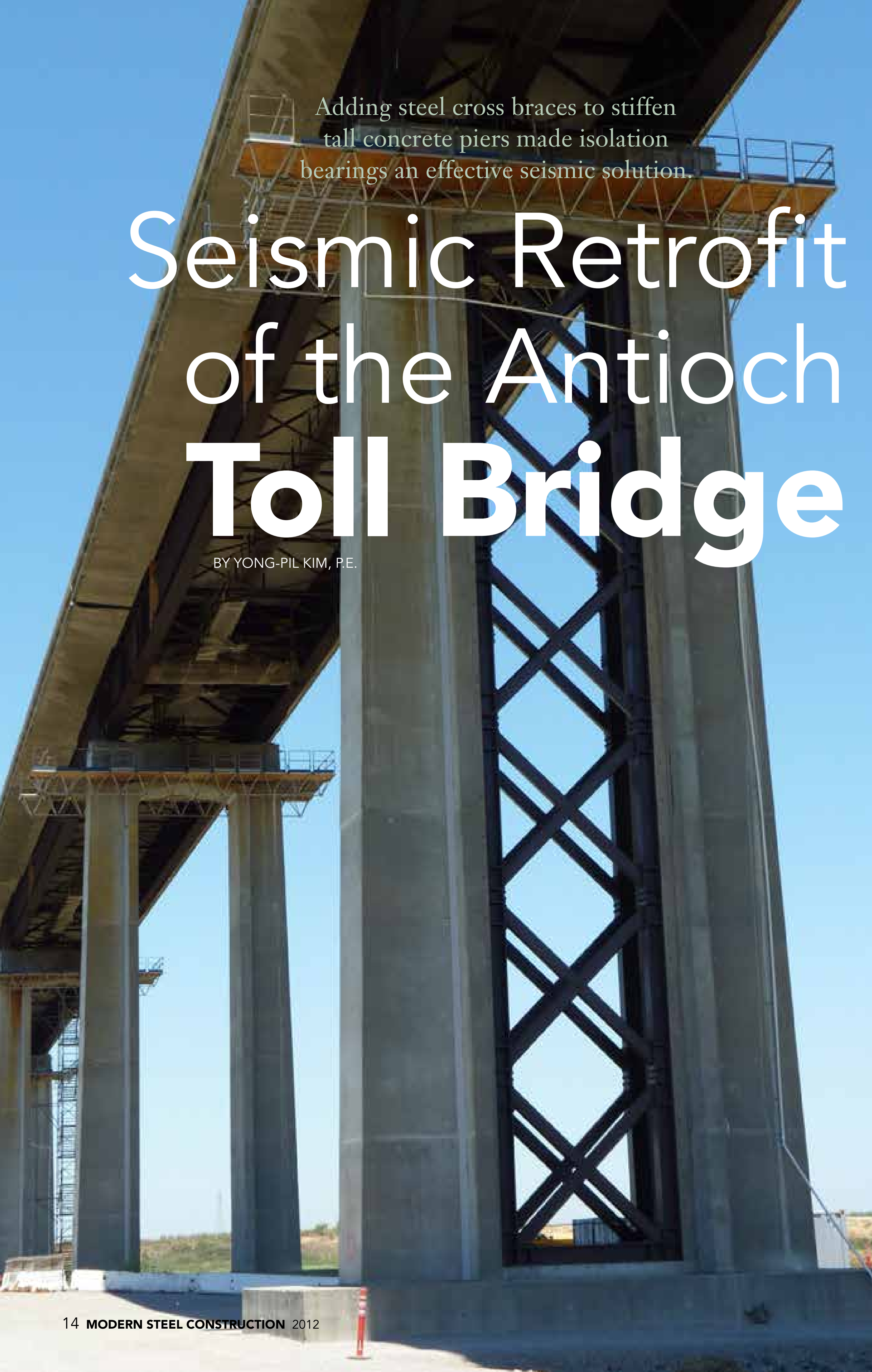
Steel Fabricator (New Bridge)
High Steel Structures Inc., Lancaster, Pa. (NSBA/AISC Member)

Steel Fabricators (Temporary Works)
Hillsdale Fabricators, St. Louis (AISC Member) and Padgett Inc., New Albany, Ind. (NSBA/AISC Member)

Adding steel cross braces to stiffen tall concrete piers made isolation bearings an effective seismic solution.

Seismic Retrofit of the Antioch **Toll Bridge**

BY YONG-PIL KIM, P.E.



Y.P. Kim

Steel braces were added to stiffen the columns of the 20 tallest piers as part of a seismic retrofit on the Antioch Toll Bridge over the San Joaquin River in Northern California.

THE SEISMIC RETROFIT of the Antioch Toll Bridge in Northern California consists of replacing the existing bearings at all 39 piers and at the abutments with seismic isolation bearings. In order to make the isolation bearings work effectively, it also was necessary to install steel bracing in the tall piers to make the pier portal frames stiffer.

Caltrans owns and operates Antioch Toll Bridge, but the funding came from the Bay Area Transit Authority (BATA), which also managed oversight of the retrofit construction. The total steel used for the cross bracing was 1,850 tons, all of which was fabricated and prime painted by Brooklyn Iron Works, Inc., Spokane, Wash. Eighty-two single-surface friction pendulum isolation bearings were supplied by Earthquake Protection Systems, Inc., Vallejo, Calif.

The main structure is 8,650-ft long with 40 spans arching over San Joaquin River. The midsection of the bridge rises as high as 147 ft to allow for ship passage. The superstructure consists of two weathering steel plate girders that are continuous over the piers. The girders are in excellent condition, having formed the expected uniform protective outer coating with no degradation in structural capacity.

Antioch Toll Bridge is one of the last two toll bridges to be retrofitted in Northern California. It was constructed in 1978, so the lessons learned from the San Fernando Earthquake of 1971 were implemented in the original design. For this reason, the bridge was long considered to have sufficient earthquake resistant features and deemed safe. However, reevaluating the bridge based on the latest seismic design criteria and an extensive geotechnical investigation, Caltrans concluded that the bridge needed to be retrofitted.

The bridge's average daily traffic is 15,000, a relatively small number compared to other toll bridges in Northern California. However, because it crosses the San Joaquin River, which is an important navigational channel, its seismic retrofit is based on the Safety Evaluation Earthquake criteria with a 1,000-year return probability. The project-specific SEE design criteria are based on "No Collapse" with permissible damages in parts of the pier pile groups and the deck expansion joints.

The analysis of the existing bridge exposed several deficiencies. First, there is a possibility of shear failure in the existing columns and the bent caps. Second, the existing rebar couplers at the base of the columns could fail prematurely. Third, the existing pile foundation system could fail undermining the stability of the bridge. In addition, the existing pin hanger hinges could fail due to possible misalignment of the girders.

Although the existing superstructure carries only two traffic lanes and is relatively light , isolating the superstructure proved to be an effective solution. Single-surface friction pendulum isolation bearings were selected for the design due to the restricted vertical clearances. Two sizes were used in order to accommodate different magnitudes in loading conditions. The larger bearings are 7.2 ft in diameter, 9.2-in. thick and have 23 in. of maximum displacement capacity. The smaller ones are 5.8 ft in diameter, 7.2-in. thick and have 20 in. of maximum displacement capacity.

By isolating the superstructure, the base shear at the piers dropped between 23% and 79%. Similar reduction in shear demand in the bent caps was observed. In addition, it reduced the tensile forces in the column vertical rebar. This will eliminate concerns about premature failure of the existing rebar splices by keeping the forces in the rebar within the yield limits. Although the retrofit reduces forces going into the pile foundation, some pile failures are still expected. Most of the pile failure will be in the exterior battered piles that will form multiple plastic hinges. Some interior piles will fail, in some piers, but based on the project-specific "No Collapse" criteria the performance of the substructure is defined as acceptable. This not only reduces the construction cost but also saves the existing river environment from any disturbance.

Yong-Pil Kim, P.E., is a senior bridge engineer at Caltrans. He has 23 years of bridge design experience and is the project engineer for the design of seismic retrofit the Antioch Toll Bridge project.

Two sets of steel cross bracing were installed to stiffen each of the taller piers, then painted brown to match the weathering steel superstructure.

Far left: The main diagonal cross braces are rectangular HSS welded at the cross joints.

Left: All frames were trial fit in the Brooklyn Iron Works shop.

Allowance had to be made for the bevel plate above the isolation bearing in addition to the thickness of the bearing itself.

Steel braces were added between the columns for 20 of the tallest piers in the mid-portion of the bridge, which range in height from 82 ft to 147 ft. The piers consist of portal frames with two hollow concrete columns linked by a hollow concrete bent cap. Because the original, unbraced frames were flexible under lateral loading, it was necessary to make them stiffer for the isolation beatings to be effective. Accomplishing this through the use of bracing also reduced the seismic loading in the columns. Steel braces were the obvious solution, because of their relatively light weight and ease of installation.

The main diagonal cross braces consist of HSS 12×8⅝ welded at the cross joints. There are two sets of bracing per pier. Each set of braces aligns with the webs of the hollow columns in the transverse direction to make the concrete and steel bracing work integrally in resisting shear. The cross braces are connected on each side to vertical W14×211 wide-flange beams, ASTM A709, Grade 50W, which in turn are connected to the columns through a cast-in-place concrete pedestal. The combination of rebar attached to the side of the existing concrete pier and the shear studs attached to the beam flange cast within the concrete pedestal will solidly link the two elements. Connection plates welded to the ends of the braces are bolted onto the inside flanges of the wide-flange beams.

Field Installation

Jacking of the girders was carried out with live traffic on the bridge deck. Only temporary road closures were necessary when lowering the bearings from the deck. A maximum of ½ in. of lifting of the girders was necessary to release the existing bearings. On many of the piers the jacking system was supported on two solid steel cylinders that were inserted into holes cored in the concrete bent cap. Simultaneous jacking was carried out at four points on each pier to unload the existing bearings.

Even though relatively thin bearings were selected it was still necessary to remove some existing concrete at the top of the bent cap to accommodate the bevel plate over the bearing and the grout pad underneath and still keep the same vertical profile of the existing bridge deck. This was accomplished by using a cable saw to cut and remove as much as 4.5 in. of the top of the existing concrete bent caps. Because this process either cuts through the exiting top transverse bent cap reinforcements or weakens their bonding, additional post tensioning was installed in transversely cored holes and lightly stressed. This will preserve the moment capacity of the bent cap. Even though some of the bent caps were up to 32-ft wide, coring through them could be achieved fairly accurately.

The bridge has four intermediate hinges that were retrofitted with an internal shear

Steel cylinders inserted through holes cored in the pier cap provided a base for hydraulic jacks, which lifted the girders to allow replacement of the original bearings with isolation bearings.

Pile Group Performance

Even with the isolation of the superstructure there will be partial failures in the existing pile groups under the design earthquake. Because the project-specific design criteria are based on preventing the collapse but not immediate functionality of the bridge, the partial failure of the pile groups after a major earthquake is acceptable as long as the bridge can still support its own weight.

All the piers have battered exterior piles, which will absorb much of the seismic forces and likely form plastic hinging in the piles. The interior vertical piles will deflect and ride out the seismic forces more easily. Due to the exterior battered piles, the pile group rigidly linked with the pile cap will not only translate laterally but also will rotate. In order to analyze the maximum displacement capacities of the pile groups, the displacement and rotational capacities of each pile group had to be calculated. This was compared with different stages of pile group failure to ascertain their ultimate capacities.

The as-built condition was analyzed with a global dynamic analysis based on acceleration response spectra (ARS) with an equivalent 6x6 matrix stiffness for the pile groups at each piers. The retrofitted bridge was analyzed with a global dynamic analysis using time histories. SAP2000 was used for the dynamic analyses.

key system in order to prevent any possible transverse misalignment of the girders with respect to each other across the hinges. The hinges are connected with a pin hanger system. Any out of plane bending would make the hinge vulnerable and although there are stay plates attached to both top and bottom flanges they are not strong enough to resist in a major earthquake.

The seismic retrofit of the Antioch Toll Bridge based on isolating the superstructure is a simple but effective solution. Implementing this scheme by adding steel cross braces to the concrete pier frames was an ideal match. Shop fabricated segments of the steel braces were field assembled with bolted connections and the bracing can be easily integrated to the existing concrete frame by connecting the two different elements through a cast-in-place concrete pedestal. Due to steel's light weight, the additional weight of the bracing could be accommodated within the capacity of the existing foundation. Not requiring a foundation retrofit meant big savings in the construction cost and also minimized the disturbance to the sensitive environment. MSC

Owner and Engineer

California Department of Transportation (Caltrans)

Steel Fabricator

Brooklyn Iron Works, Inc., Spokane, Wash. (AISC Member)

General Contractor

California Engineering Contractors, Inc., Pleasanton, Calif.

wsbs preview

AESTHETICS OF URBAN STEEL BRIDGES

Bridge engineers should take responsibility for the structure's appearance, as well as ensuring that it carries the load.

BY JUAN A. SOBRINO, P.E., PH.D.

Fig. 1. Girona pedestrian bridge.

THE AESTHETICS of a bridge play a role as important as efficiency, economy, sustainability and constructability. Bridges, as long-lasting structures, modify the landscape and their influence in the life of various generations is something we cannot forget in their planning and design. Good architects and engineers have this concept—"the significance of the appearance"—always present when they conceive a house, a building or a transportation infrastructure.

There are many bridges out of context that have irreversibly damaged natural and urban landscapes. Too many bridges are devoid of any creativity, unattractive, and both badly conceived and built. These anodyne works have caused civil engineering to lose its good reputation.

Unfortunately, the design of most modern bridges is based only on cost and efficiency. Cost and value have long been confused in bridge design. This is a strange contradiction, because the communities feel linked to and proud of their city, if public spaces are taken care of, if aesthetics are present, if history and culture form part of the city's tradition, along with other intangible values related to beauty.

In the last decade, poor bridge designs have resulted in the construction of landmark bridges that want to be different, usually out of scale, and neither efficient nor economic. Political demagogy has also had its consequences, and manifests itself in some leaders that, unable to decide or to accept technical advice in such matters, transfer those decisions to lay people. These spectacular landmark bridges are creating confusion in both the public and bridge owners. There is a feeling that aesthetics cost more money, but this is not true. Luxury costs more money, but that is not necessarily true of aesthetics.

Fortunately, there are many tools and resources to help in designing expressive, attractive bridges. We engineers are conscious of the importance of properly selecting the structural type, the shape, the dimensions, the relationship between the bridge and the site as well as among different bridge elements, the design of details, the color and the textures. All of these aspects, combined with a technical approach to analyzing the efficiency and the economy on a life-cycle cost basis, plus using CAD and virtual simulation techniques, allow bridge engineers to make the right decisions.

Urban bridges with small or medium spans offer an opportunity to explore new forms and construction methods, because the cost of construction depends mainly on the free span and the material, as long as they can be built using conventional methods. In urban zones the cost of the finishes, the restrictions of the site, the services affected, and the traffic disruption can approach the cost of the structure itself. The limit is an ethical matter. We work with taxpayer money

➤ Fig. 2. Andoain pedestrian bridge.

and the engineer's duty is to make responsible use of these public resources. An engineer's real challenge is to conceive aesthetic bridges with no cost increase.

Steel bridges offer great aesthetic possibilities to bridge designers in addition to the advantages in erection, rapid construction and sustainability. If each bridge is unique, why not explore the enormous opportunities in steel construction now open to us with the use of CAD/CAM and numerical control techniques?

Pedestrian Bridges with Structural Railings

Railings are important elements of a bridge, as pedestrians are close and can touch them. The form, color and materials selected for railings are crucial for the appearance of the bridge.

An interesting idea is to design railings, which are always present, as structural components to increase stiffness and to reduce the visual depth of the deck. This concept has been used in several pedestrian bridges we designed in Spain.

The pedestrian bridge designed in Girona, from 1996, crosses the Onyar River 60 miles north of Barcelona. This structure is a frame with one span of 190 ft that is supported on reinforced concrete blocks integrated into the existing embankments. The main part of the bridge deck is a weathering steel box girder made up of stiffened steel plates with a 50 ksi yield strength (Figure 1). The typical cross-section is a unicellular box girder with a top flange 7.9-ft wide with its depth varying between 2-ft (*L*/97) at mid-span and 5.6-ft (*L*/34) at supports. The girder is very slender thanks to the structural railings, which are connected to the box girder. The presence of the ribs creates shadows on the web surface creating an attractive 3D effect. The final result, a sober and simple shape, conceals a complex process of searching for the optimum design, but is at the same time exciting. The weight of steel girder is only 46 tons.

The same concept used at Girona was applied in 2005 to a longer pedestrian bridge in Andoain, in Spain's Basque Country. The main span is 223 ft and the box girder depth varies between 3.1ft (*L*/71.6) at center span and 5.6 ft (*L*/40) over the supports (Figure 2). The overall weight of steel is only 103 tons.

This idea of using the railing as a part of the structural system was pushed to the limit at the pedestrian bridge in Matadapera, which is in the Barcelona Province, Spain. The solution consists of a very slender steel box girder with a length of 571 ft. The typical cross-section is a unicellular box girder at the extremes that is transformed into an extremely slender multicellular box girder of only 8.3 in. at mid-span (Figure 3).

▲ Fig. 3. Matadepera pedestrian bridge.

Juan Sobrino, P.E., Ph.D., is the founder and president of Pedelta, Inc., Coral Gables, Fla., with additional offices in Pennsylvania, Spain and Latin-America. He has been involved in the concept or design of more than 500 bridges worldwide and has promoted the use of advanced materials in bridge construction. He is collaborating as a part-time docent on structural analysis and conceptual bridge design with the Technical University of Catalonia, Barcelona, Spain, and with Carnegie-Mellon University, Pittsburgh, respectively.

Innovative Bridges with Stainless Steel

Fundamental advances in structural engineering have clearly been related to the use of new materials along the history of construction. The increase in the use of advanced materials in bridge design can partially be attributed to the growth in awareness of owners about the use of materials that require reduced maintenance in addition to having greater mechanical resistance and capacity to be reused.

In 2005, we designed the first European road bridge with a complete duplex stainless-steel structure at Cala Galdana, in Minorca, Spain. Minorca is a Mediterranean island that was declared a reserve of the biosphere by UNESCO and Cala Galdana is one of its most beautiful beaches. The surroundings are only partially urbanized, and they contribute to the island's attractiveness to tourists.

The bridge had to replace an existing concrete bridge that was only 30 years old but exhibited significant degradation due to the corrosive marine environment. The new bridge had to meet four explicit owner requirements. It had to be environmentally friendly, have high durability, require minimum maintenance and be a symbol of innovation. For these reasons duplex stainless steel was selected.

The structural systems consist of two parallel arches with a free span of 147.6-ft and an intermediate deck (Figure 4). The main structure is made of Grade 1.4462 duplex stainless steel, which exhibits a high resistance to corrosion by chlorides. The arches, with a total rise of 19.7-ft, have a triangular cross-section with a central web. Its 2.3-ft depth is constant throughout its overall length. However, the width of the section varies between 2.3-ft and 3.3-ft. The use of a triangular cross-section produces a very apparent slenderness. The deck is made of reinforced concrete connected to a series of transverse floor beams. The use of stainless steel introduced some difficulties, in particular in the treatment of the surfaces, and some specific rules had to be applied.

▲ Fig. 4. Stainless-steel road bridge in Minorca.

▼ Fig. 5. Stainless-steel pedestrian bridge in Sant Fruitós.

One of the main concerns when using stainless steel is the increase of construction cost. In this particular case, we estimated that the increase of cost will be offset in 80 years due to the minimum maintenance required.

In 2009, a pedestrian bridge combining stainless-steel and glass fiber reinforced polymer (GFRP) panels for the floor was built in Sant Fruitós, near Barcelona. In this pedestrian bridge we combined a traditional structural type, the arch, with advanced materials. The arch is connected to the deck to avoid horizontal forces at the supports. The deck is very slender and has a triangular cross-section with transverse ribs supporting the GFRP planks. This structure is very light and transparent and very easy to maintain.

The inclined arch is designed to generate a more expressive structure without significantly increasing the cost of the structure. The structural system is very effective, which was confirmed in the static and dynamic tests. The lighting system is also crucial to achieving a warm atmosphere during the night (Figure 5).

Abetxuko Bridge

The Abetxuko Bridge, completed in 2006, crosses the Zadorra River in Vitoria, Spain. It is intended as a vindication of an open and creative engineering design, which meanwhile does not exclude the traditional engineering approach. New forms have intentionally been sought in an attempt to escape from standard geometry (Figure 6).

The bridge replaced an old and very narrow (19.7-ft-wide) bridge with a poor hydraulic capacity. Crossing the old bridge was risky for pedestrians and the municipality decided to improve the mobility of the users.

However although the bridge is intended to be a landmark, its structural system is very simple. The bridge is a continuous structure with three spans of 85 ft, 131 ft and 85 ft and with a total deck width of 103 ft, carrying four road traffic lanes, a central light rail line with two tracks, and two pedestrian walkways. The structural system consists of two parallel trusses with organic forms, their dimensions adjusted according to the structural analysis. The flow of the Zadorra River is safeguarded because the structure has two longitudinal steel trusses and a steel-concrete deck supporting the traffic. The trusses, which ultimately support the deck and the traffic, are arranged with a large part of their structure above the deck. This allows the level of the new road to be raised to meet the hydraulic requirements.

The uncomfortable experience felt by pedestrians on the old bridge was reversed so that they are in a privileged situation on the new bridge. Pedestrians cross the river on external walkways of the bridge, protected from the traffic by the organic structure and enjoying the best views of the river.

The irregular, curvaceous forms of this bridge are in defiance of the traditional use of symmetry, purity and order in engineering design. The chosen material, weathering steel, is intended to show the expressivity of the structure and the choice of weathering steel is also a reference to the history of the Basque country. The color of this steel alters over time; together with the irregular shadows generated by the curves of the structure, it is intended to create the idea of a "living" bridge.

The total weight of steel used in the bridge is about 671 tons (43 lb/ft^2). The total cost of the structure was approximately \$150 per ft^2, which is only about 10% to 15% more than a standard composite bridge of the same dimensions.

Fabrication of the complex steel structure was carried out at one steel yard in Vitoria. The process included preparation of drawings, definition of the pieces, cutting, preparation of plate edges, bending of curved plates, pre-assembling, welding of stiffeners, assembling of the segments, and transport to the site and the erection of the sections and welding of the rest of the steel members. The process of fabrication illustrates the enormous possibilities available through CAD/NC techniques. As the inner surfaces of the steel structure will be inaccessible, the members were made completely watertight.

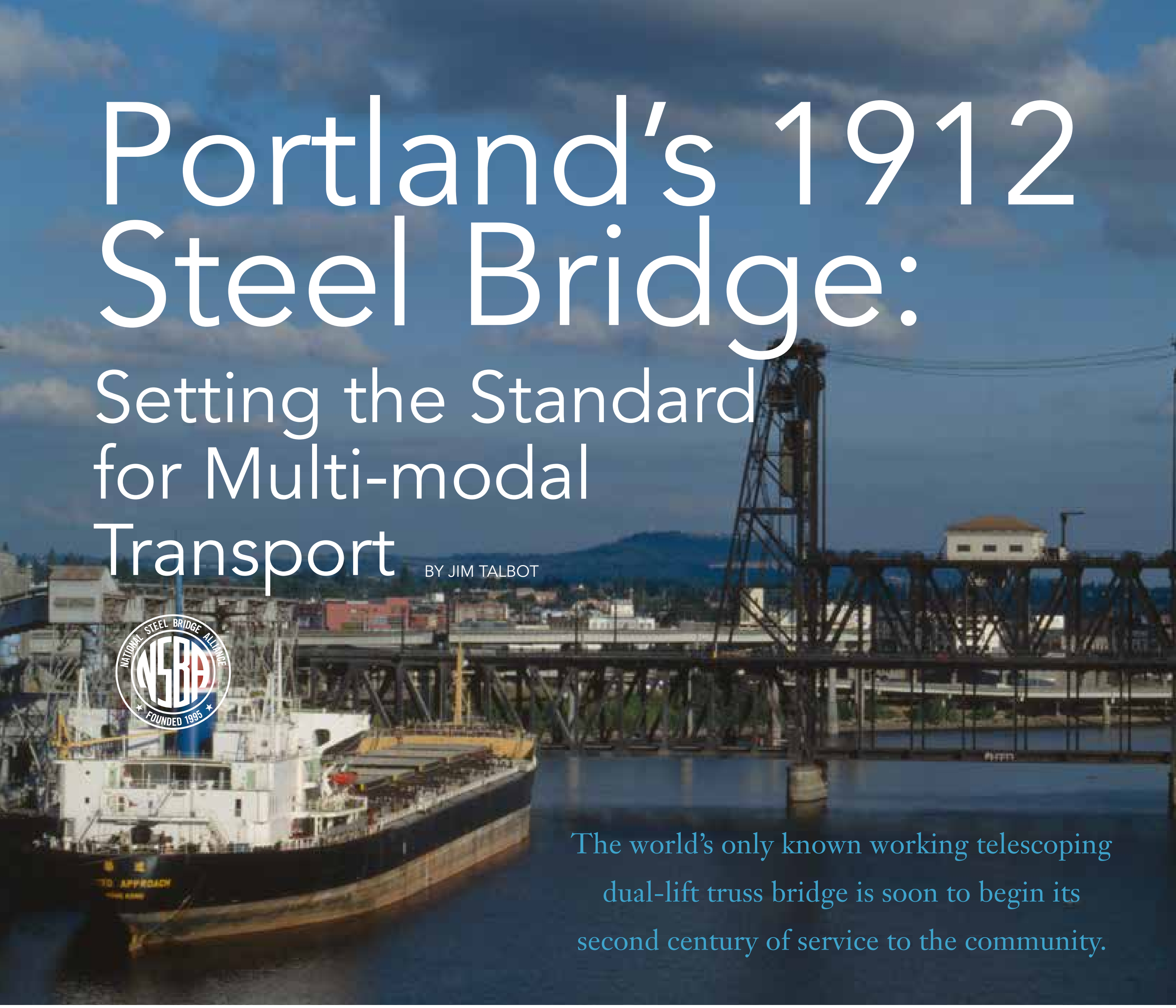
Conclusion

Bridge engineers have a very creative profession, but we should improve our designs through adopting an open and flexible view, providing not only cost-effective bridges but also caring about their aesthetic aspects. An open and creative engineering design does not exclude a traditional engineering approach.

Steel provides excellent possibilities for bridge designers to create innovative structures that transmit beauty and goodness at a reasonable cost. We just have to explore how to do it. MSC

The author of this article will present additional international perspectives in session B6, "Ideas From Abroad," at the World Steel Bridge Symposium, April 18-20 in Dallas. Learn more about the World Steel Bridge Symposium and NASCC: The Steel Conference at ***www.aisc.org/nascc****.*

◄ Fig. 6. Abetxuko Bridge in Vitoria.



Portland's 1912 Steel Bridge:

Setting the Standard for Multi-modal Transport

BY JIM TALBOT

The world's only known working telescoping dual-lift truss bridge is soon to begin its second century of service to the community.

Jim Talbot is a freelance technical writer living in Ambler, Pa.

IN THE MID-19TH CENTURY, the Columbia and Willamette Rivers carried major seagoing traffic to and from the inland port city of Portland, Ore. As Portland grew to be a major shipping port for wheat, lumber, and other commodities, these two major rivers running through the city presented major obstacles to local travel.

By 1853, ferry service began across the Willamette River, but not until 1887 did the first Morrison timber bridge with a wrought-iron swing span cross the Willamette. It was followed a year later by the original Steel Bridge, a double-deck swing-span railroad bridge. Its name derived from the fact that in 1888 steel represented an unusual bridge-building material. The additional bridges that followed contributed greatly to the growth of Portland, which by 1900 had grown to 90,000 inhabitants.

A Replacement Steel Bridge

Early in the 20th century, the Oregon Railway and Navigation Company, which today is the Union Pacific, and the Southern Railroad made plans to replace the original Steel Bridge. Although the intent was to carry only passenger and freight trains, the city insisted

Jet Lowe, from the Library of Congress HAER

The Steel Bridge, Portland, Ore.

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.

on an upper deck for road and pedestrian traffic. The new bridge, being essentially on the same site and of the same material, took on the Steel Bridge name. It opened for trains nearly a century ago, on July 21, 1912, and less than a month later for vehicles and pedestrians.

The 1912 Steel Bridge is the second oldest vertical-lift bridge in North America and is the only known working telescoping dual-lift truss bridge in the world. The lower deck retracts neatly into the upper deck girders, permitting vehicles to continue crossing the upper deck undisturbed.

The bridge continues today as the epitome of multi-modal transport. The upper deck has two light-rail tracks bracketed by one lane for automotive traffic and a 6-ft-wide pedestrian lane on each side. The lower deck carries two railroad tracks and has an 8-ft cantilevered pedestrian/bicycle lane on its southern side. The average daily traffic in 2000 was 23,100 vehicles (including numerous buses), 200 light-rail trains, 40 freight and Amtrak trains, and 500 bicycles. Adding the lower-deck walkway in 2001 sharply increased bicycle traffic; by 2005 it had grown to more than 2,100 daily, many bound for the Eastbank Esplanade on one end of the bridge or Portland's downtown Waterfront Park on the other.

Design and Construction

Prolific civil engineer John Alexander Low Waddell, along with his mechanical engineer John Lyle Harrington, designed the $1.7 million 1912 replacement as a through-truss, double-deck, double-lift steel bridge. The lower deck served to carry passenger and freight trains and the upper deck horse-drawn carriages, automobiles, and electric trolley cars. The firm of Waddell & Harrington designed more than two dozen vertical lift bridges while their partnership existed between 1907 and 1914, and Waddell went on to design many more lift bridges over the course of his lifetime.

Harrington contributed the bridge's ingenious lift mechanisms. Small components included equalizers that distribute weight among the ropes and the guides that keep the spans in alignment as they move. The telescoping vertical members and the system of ropes, sheaves and counterweights are examples of larger novel contributions. Harrington claimed that with proper maintenance, such as renewal of decks and cables, occasional painting, and daily lubrication, his bridges would be "permanent." Now, as the structure completes its first century of service, his claim sounds much less far-fetched than it must have in the bridge's earlier days.

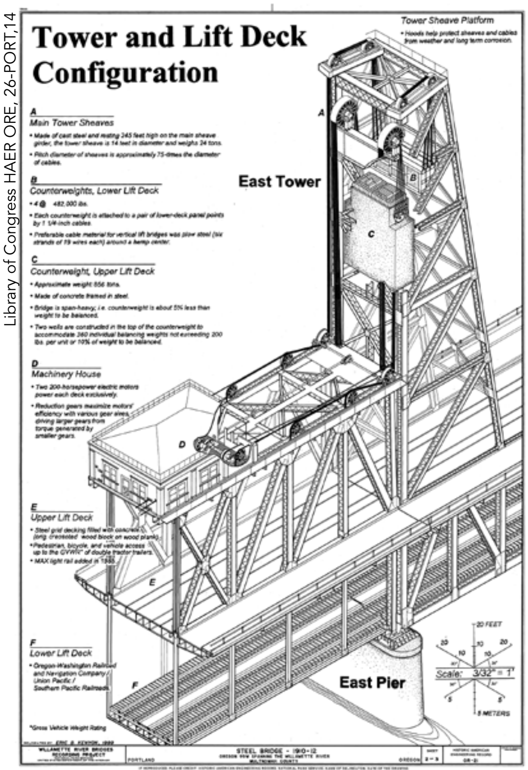
Constructing the Steel Bridge took two years. The Union Bridge Construction Co. of Kansas City, Mo., built the piers and Robert Wakefield of Portland erected the trusses, towers, and lift span. The design included a wrought-iron woven lattice railing for the top deck as its only decorative embellishment.

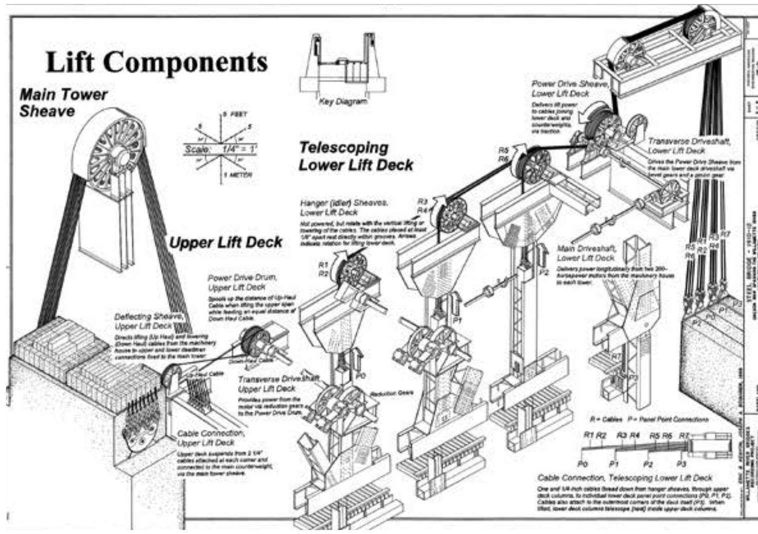
The record-setting loads of counterweights and lift-spans demanded innovative engineering to erect. Elaborate travelers, falsework and ramps facilitated erection of the lift towers and mechanisms. Massive posts and lower chords, each measuring a yard or more in width and depth, help the century-old structure continue to safely carry its multi-modal transports.

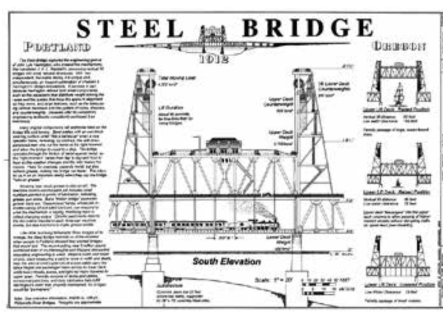
Double Lift Raises

The lift span of the bridge extends 211 ft. The lower lift span consists of vertical steel members while the upper one has both vertical and diagonal members. Two secondary steel through-Pratt truss spans on either side of the lift span, about

Library of Congress HAER ORE, 26-PORT,14







These highly detailed, annotated illustrations of the mechanical and structural systems from Portland's Steel Bridge, the only working double-deck, double-lift span in the world, can be found at www.steelbridges.org/PortlandCenturion.

290 and 300-ft long, complete the river crossing. The typical top deck width runs to 74.5-ft (62.5 ft for the roadway plus two 6-ft sidewalks). The sidewalks flare out at the towers, taking the maximum width to 77 ft.

This Steel Bridge is believed to be the world's only double-deck bridge with independent lifts. The operator can raise the lower deck 72 ft; the lower lift truss smoothly "telescopes" into the upper lift truss. The operator also can raise both decks, providing 163 ft of vertical clearance above the water. Two counterweights serve the upper deck, and eight the lower, totaling about 4,500 tons.

The machinery house sits above the upper-deck lift span with the operator's room suspended below it, allowing the operator to view both the river traffic and the upper deck. The operator can raise the lower deck 45 ft in about 10 seconds, and the upper deck at a rate of 1-ft per second. As in other early American machine rooms, colorful paint patterns added decoration and function. Small painted numbers indicated points of lubrication. Oilers charged with wiping excess extruded lubricant from metal-on-metal movements would soon learn to determine optimum lubricant amounts.

With experience, operators learned just when to cut the motor, allowing lift sections to coast to a stop and avoiding the need to apply band brakes. The exact instant to cut motors changes with the weather and grease applications during the day. The band brakes have an oak block wearing surface, exuding a barbecue-like smell when applied—as during operator training.

The lower deck offers relatively low clearance above the water: 1 ft at high water and obviously no clearance at flood water. Major floods threatened the lower deck in 1948, 1964 and 1996. The 1948 flood submerged the lower deck in 5 ft of water. During the 1964 and 1996 floods, water touched the lower deck.

Lower deck raisings have continued to diminish through the years. In 1914, operators raised the lower deck 20,339 times for river craft. Lower deck annual raisings declined to 10,687 and


Michael J.W. Goff

The Steel Bridge, Portland's century-old mechanical marvel.

3,000 in 1943 and 1988 respectively. Now it's the practice to keep the lower deck up when no train crossings are scheduled.

Later Developments

Originally, as noted earlier, the upper roadway deck included rails for the city's first electric trolley cars. With the decline in streetcar use, the rails were removed in mid-century. In 1950 the Steel Bridge became a significant portion of a new U.S. 99W highway. In 1986 rails returned when a $10 million rehabilitation project added the cross-river portion of Metropolitan Area Express (MAX) light rail system, which is part of TriMet, the public transit agency for the Portland metropolitan area.

In 2001, another project installed a 220-ft-long, 8-ft-wide cantilevered walkway on the south side of the bridge's lower deck, raising to three the number of publicly accessible walkways across the bridge, including the two narrow sidewalks on the upper deck. Oregon DOT closed the upper deck in the summer of 2008 for maintenance and to allow a junction to be built at the west end for the MAX Green Line.

Union Pacific owns the bridge, which is the most complete and complex transportation link in the city, and leases the upper deck to the Oregon DOT, which subleases to TriMet. The City of Portland takes responsibility for the approaches. Today, as it turns 100, the black, towering Steel Bridge dominating the skyline at Willamette River mile 12.1 is the most well-known among Portland's world-class collection of bridges. MSC

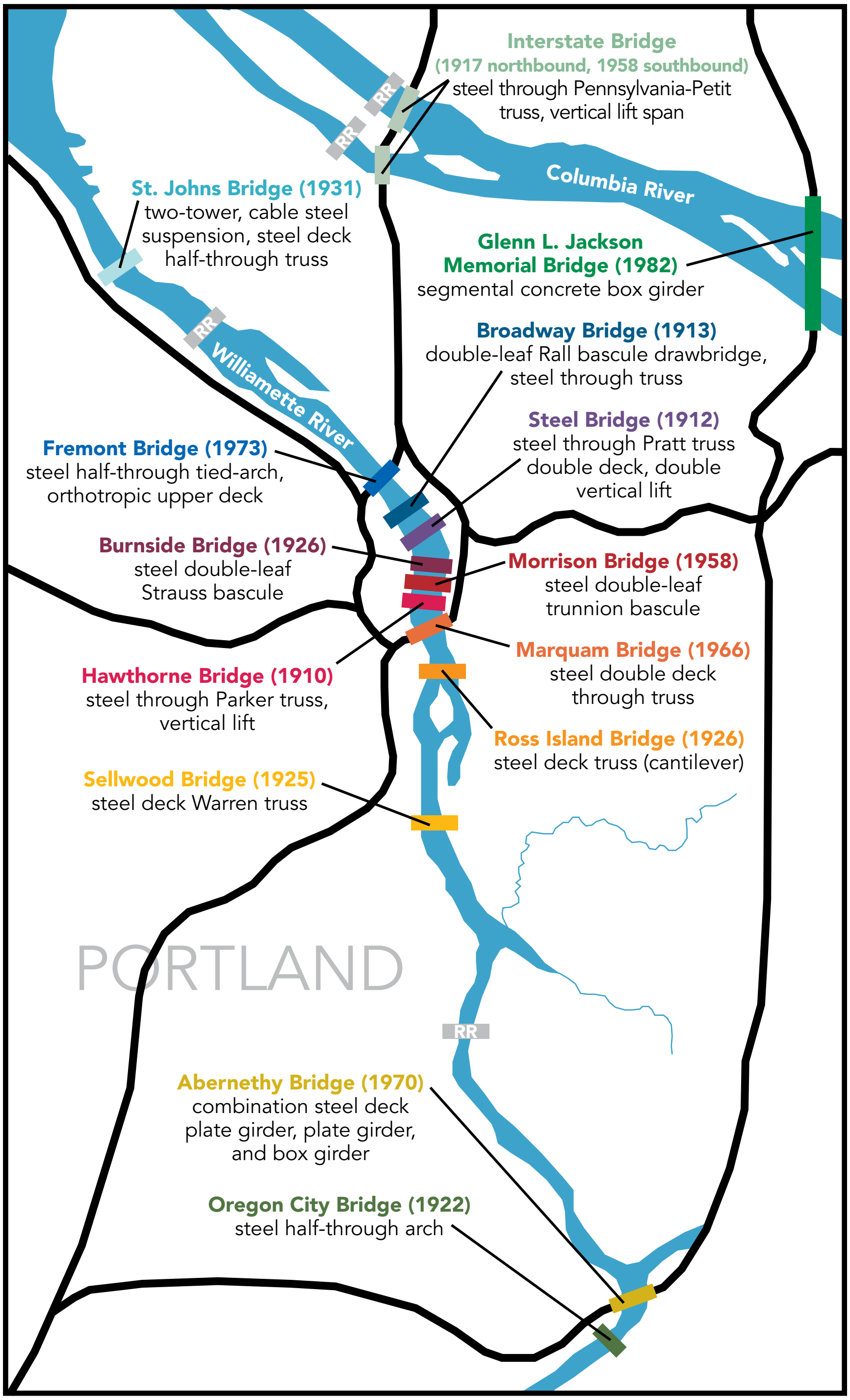
A City of Steel Bridges

The bridges of Portland, Ore., number 14, or 17 if you count the railroad–only crossings. Twelve vehicular bridges are concentrated on the Willamette River between St. John's and Oregon City, and two interstate bridges cross the Columbia River into the state of Washington. These are supplemented with three important railroad structures.

Portland's bridges have contributed greatly to its growth. The city population, according to the 2010 census, now numbers about 580,000, and about 2.6 million people live in the Portland metropolitan area. The citizenry originally concentrated downtown on the Willamette's west bank. New bridges encouraged migration to the east bank, which is now home to 80% of the population.

The PDX Bridge Festival each summer sponsors an annual, citywide cultural arts festival that celebrates the Willamette River Bridges. This organization considers the bridges "central to regional identity, tying the geography and cultures of Portland into a vibrant whole."

Other cities may have more bridges (New York City boasts 75), but Portland's represent a varied catalog of bridge types, some unduplicated anywhere. Included are the world's only telescoping double-deck, double-lift bridge (discussed here), plus the world's oldest vertical lift bridge and the longest tied-arch bridge. The significant vehicular bridges are shown in the map on the right, including dates of completion and bridge type.



bridge crossings

WEATHERING STEEL FOR HIGHWAY BRIDGES

By addressing corrosion concerns, weathering steel offers a sustainable and aesthetic solution for designers and owners.

BY ALEX WILSON AND BRIAN RAFF

APPROXIMATELY 40-45% of all steel bridges today are being built with some form of weathering steel. Weathering steel is typically a high-strength, low-alloy steel that, in suitable environments, forms a tightly adherent protective rust "patina" that acts as a skin to prevent further corrosion to the steel beneath. Since its development in the 1930s, many U.S. steel producers have offered corrosion-resistant, weathering steels as part of their product lines.

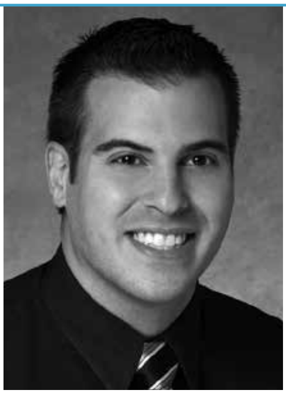
Current weathering steels are supported by the American Association of State Highway and Transportation Officials (AASHTO) Specification M270, which corresponds with ASTM A709, and can be acquired in grades 50W, HPS70W, and HPS100W where these numbers correspond to each grade's yield strength in ksi. A new generation of high-performance steel (those grades prefixed with HPS) provides weathering performance with a slightly greater resistance to atmospheric corrosion than its predecessors.

Tips to Ensure Success

Detailing: As with bridges built of any material, the performance of the structure often is controlled by the types of details used. Details for weathering steel bridges must be such that they will not trap water. If weathering steel remains wet more than 60% of the time—regardless of the cause of wetness—it will not perform as intended. Because it can be difficult and costly to prevent debris (e.g., pigeon nests) from building up on horizontal bridge components, it is imperative that bridge inspectors brush off this debris during their biennial inspections. This simple act will prevent the debris from holding moisture in contact with the steel, thus ensuring long-term performance.

Marine Environment Applications: The FHWA Technical Advisory 5140.22, "Uncoated Weathering Steel in Structures," (**www.fhwa.dot.gov/bridge/t514022.cfm**) provides guidance with regard to proper environment, location, design details and maintenance of weathering steel. It recommends the use of a "wet candle" test method to determine the level of airborne salts, with a limit above which the FHWA advises "caution." However, this test is very time consuming. A more practical approach is to evaluate performance of other types of steel structures in the general area of the proposed structures, and if excessive corrosion is not observed, then weathering steel will perform successfully. Chemical analysis by a corrosion specialist of the oxides/rust formed on other weathering steel structures in the vicinity of the location in question is also another technique to judge applicability. Since the mid-1970s, weathering steel has been performing well in applications literally within a few feet of bodies of salt water. Performance on these structures is more than adequate, and this performance level is expected to continue.

High Rainfall, Humidity or Fog: As with the performance of weathering steel when details trap water, if the environment is such that the steel will remain wet more than 60% of the time, then it will not perform as intended. An example of where the use of weathering steel is inappropriate is in the northwest U.S., where rainfall approaches 200 in. per year. However, in areas subjected to annual rainfall of even as much as 100 in. per year—and in areas with high humidity—structures with uncoated weathering steel are providing excellent performance



Alexander D. Wilson is chair of the Steel Marketing Development Institute's Steel Bridge Task Force and very active with NSBA members. He has been influential in the development of bridge material specifications and was influential in the development of the latest high-performance steel (HPS70W). He has been this generation's key resource for metallurgical information on steel bridges. Brian Raff is marketing director for the National Steel Bridge Alliance and is responsible for providing strategic leadership and executing the national marketing program that builds market share for steel bridges.

even after many years in service. The key is to provide an environment with a consistent wet/dry cycle because moisture activates the corrosion process, but the oxide layer obtains its nonporous state in its drying state. The faster the wet and dry states cycle, the more consistent and even the patina will be.

In both marine environments and those with high rainfall, humidity, or fog, a more in-depth evaluation can be made by following the wet candle method from ASTM G92, Characterization of Atmospheric Test Sites, and using ASTM G84, *Measurement of Time-of-Wetness on Surfaces Exposed to Wetting Conditions as in Atmospheric Corrosion Testing*, or by consulting with a corrosion specialist.

Bridge Joints: Regardless of the type of material used in the superstructure, a main cause of structure deterioration is the poor performance of bridge joints. The FHWA Technical Advisory referenced above also recommends use of "jointless" bridges wherever possible as a cure to this ever-present problem. Weathering steel used in conjunction with jointless bridge design has performed well. Integral and semi-integral abutments, in addition to just extending the deck slab over the abutment backwall, are ways to achieve the benefits of jointless bridges. Further guidance and details are available in "Performance of Weathering Steel in Highway Bridges—A Third Phase Report," available on the AISI website (**www.steel.org**) at **http://bit.ly/xuN5rO**. Where joints must be used, properly detailed troughs under all types of bridge joints must be used to ensure long-term protection.

Staining of Substructures: When weathering steel is directly exposed to rainfall—either temporarily during construction or permanently due to bridge detailing—concrete elements below will be stained by the rust-colored water that runs off. This problem is prevented during construction by simple and inexpensive techniques that include wrapping the substructure units with plastic until the deck slab is placed, precoating the concrete surfaces with a sealer, or requiring the stains to be removed by blast cleaning after construction. For areas where the steel is permanently exposed, detailing the tops of the substructure to channel the staining water into grooves in the concrete surface has been used successfully. This provides a streaked appearance that actually enhances the otherwise rather bland color of the concrete wall. Should staining occur that needs to be removed, there are commercial products available that are very successful in removing the stains.

Fatigue Cracking: State-of-the-art designs of steel structures, including those built with weathering steel, should be immune from the fatigue cracking that may occur on older structures that were built before a full understanding of the phenomenon emerged. However, sometimes a detail that is fatigue-sensitive still shows up on a newer bridge. Therefore, inspectors must be continually vigilant to ensure that fatigue cracks are discovered before they reach the point at which unstable crack growth can occur. Fatigue cracks in weathering steel are readily apparent because they exude an orange dust that contrasts with the deep brown color of the steel itself. These cracks may even be more

Ironworkers prepare to field splice the plate girders on the West Virginia approach to the Blennerhassett Island Bridge, which used high-strength, high-performance 70 ksi weathering steel for maximum durability and improved ductility.

◄ Where appearance dictates a painted bridge, painting only the fascia side of exterior girders will provide most of the cost benefits of weathering steel while still satisfying aesthetic requirements.

◄ The color of the weathering steel changes during the first few years as the protective patina is forming.

visible than ones that occur in painted structures.

Painting: The FHWA strongly recommends that the ends of beams and girders under bridge joints be painted for a minimum distance to protect against the certainty of joint leakage. The paint system used for weathering steel should be high-quality paint as would be used for any other steel bridge. Where the painted surface is exposed to view, the color of the paint should match the color of the "weathered" steel. Note that this color changes during the first several years of service as the protective patina forms on the steel. One recommended specification to achieve this is Federal Color number 30045. In some instances, aesthetic needs require a painted bridge. To provide most of the cost benefits of weathering steel while still satisfying aesthetic requirements, only the fascia side of exterior girders need be painted. For structures built with joints, and for those built before the FHWA Technical Advisory was issued with its recommendation to paint the steel below the joint, it may be necessary to paint steel that has been contaminated with the saltwater coming through the joint. Recommended paint systems for this application are included in the FHWA Research Report RD-92-055, *Maintenance Coating of Weathering Steel: Field Evaluation and Guidelines*, available online in the National Transportation Library, Bureau of Transportation Statistics, at **http://1.usa.gov/zPCjiK**.

Improvements and Research

The Federal Highway Administration (FHWA) is making an effort to develop a deeper understanding of weathering steel bridge performance and to provide more detailed guidance on proper application. Research is under way involving 3D numerical simulations of truck passage events at bridges using computation fluid dynamics (CFD) to quantify the amount of salt spray that is deposited on the girders and how this might be influenced by various geometric parameters. Also, FHWA has plans to perform a national study of weathering steel bridge performance in various micro and macro environments. These efforts will provide data for improving the guidance by better definition of "tunnel-like conditions" and/or "coastal environments" to name a few. FHWA is working with the American Iron and Steel Institute (AISI) Corrosion Advisory Group on other projects as well.

Engineers have expressed concern with section loss as part of the weathering process. However, the order of section loss expected to establish the protective patina amounts to around 100 mils (0.1 in.), a negligible amount when assessing structural performance. It is also important to keep in mind that because rolling tolerances generally result in a greater thickness than specified, even after many years in service, a weathering steel bridge will usually have a greater thickness than required by the origin design.

When excessive section loss does actually occur, it is very obvious and is in the form of "laminar" rusting of the surface. This occurs primarily under the all-too-common leaking bridge joints when deicing chemicals are used on the roadway above. Wherever laminar rusting is observed, it is imperative to locate the source of the corroding water, and if possible, seal it off. If it is not possible, then spot coating of the affected area may be necessary (see painting tips below).

Additional Resources

Much more information is available to assist those concerned with the use of weathering steel in highway bridges. Here are three recent publications that can be particularly helpful.

- "Uncoated Weathering Steel in Structures", FHWA Technical Advisory 5140.22, October 1989, **http://1.usa.gov/yhP3je**.
- "Improved Corrosion-Resistant Steel for Highway Bridge Construction Knowledge-Based Design," FHWA TechBrief, August 2009, **http://1.usa.gov/A8ddO3**.
- "Steel Plate Availability for Highway Bridges," *Modern Steel Construction*, September 2011, **http://bit.ly/wSVrqp**.
- "Weathering Steel: For unpainted bridges and general construction," ArcelorMittal USA, December 2012, **http://bit.ly/wNdMza**. MSC

This is the first in a series of updates to the Bridge Crossings columns originally published in MSC *beginning in 1996. The authors would like to acknowledge Robert L. Nickerson, P.E., who wrote the original column on this topic.*

The National Steel Bridge Alliance was formed in 1995 to enhance the design and construction of domestic steel bridges. A division of the American Institute of Steel Construction, NSBA assists fabricators, designers and owners in making the best design selections possible, while also establishing steel as the material of choice for bridges. Beyond our membership, NSBA brings together the agencies and groups who have a stake in the success of steel bridge construction, including representatives from AASHTO, FHWA, state DOTs, bridge consultants, and representatives of the coatings, fastener and welding industries. From more information, go to **www.steelbridges.org**.

conference preview

STEEL BRIDGES LINK TEXAS HIGHWAYS

Tub girders easily handle the long spans on a prominent Dallas-area interchange.

BY GREG KOCHERSPERGER, P.E.

DRIVING LONG DISTANCES is a reality for many in the Metroplex (also known as the Dallas-Ft. Worth area). And as the area continues to expand, so does the need for an additional high-volume, high-speed roadway to ease the burden of getting there from here.

With the recent completion of the Eastern Extension of the President George Bush Turnpike (PGBT), the North Texas Tollway Authority (NTTA) has completed a vital link and increased mobility between outlying cities to the west and north of Dallas.

Critical to accessing this new extension is the interchange at Interstate 30, constructed by the Texas Department of Transportation (TxDOT). The interchange consists of four direct connector ramps linking the PGBT main lanes to the reconstructed I-30 main lanes. The direct connectors consist of a single-lane ramp supported primarily on pre-stressed concrete U-beams with spans varying from 80 ft to 100 ft. As the bridges cross the I-30 frontage roads and main lanes, however, steel superstructures are required to accommodate the longer spans and the tighter horizontal curvature they involve.

Trapezoidal steel box girders, with spans up to 255 ft, were chosen to match the appearance of the concrete U-beams and for their desirable aesthetics. Where column placement could not be accommodated within the interstate main lanes, steel box straddle bents were used to support the tub girders and reduce the required spans. All structural steel on the project is ASTM A709 Grade 50W weathering steel, providing a uniform aesthetic with other projects in the Dallas area and reducing maintenance costs for both TxDOT and the NTTA.

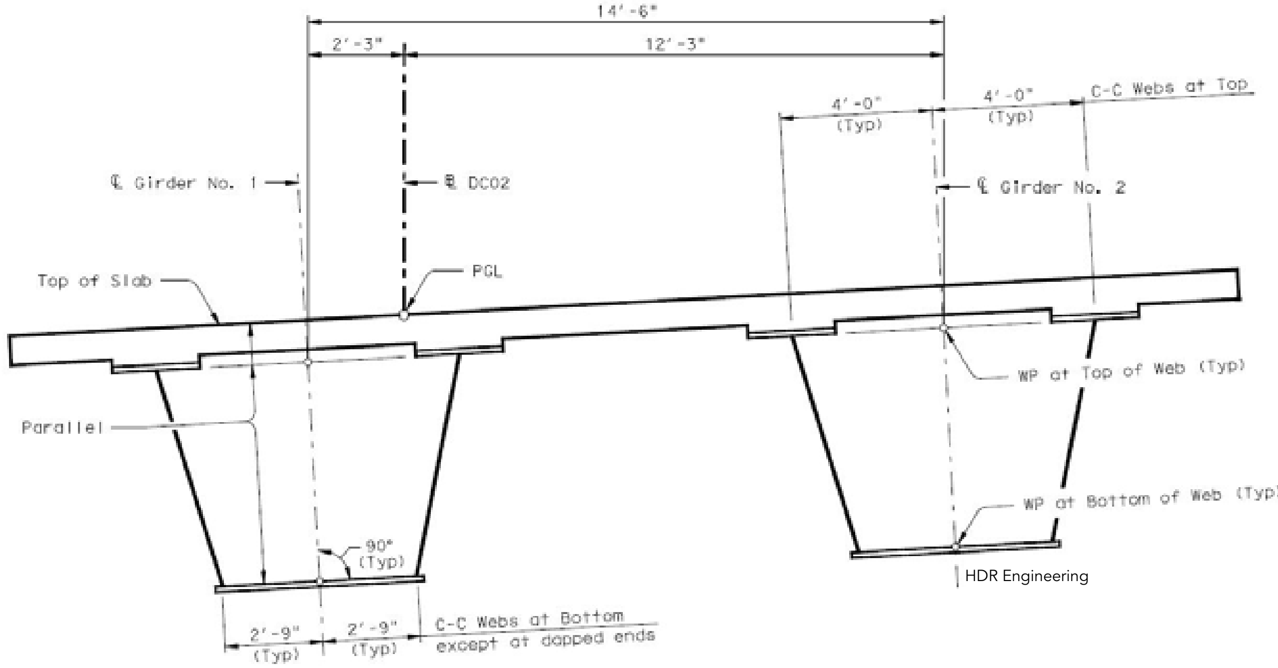
Steel Trapezoids

The project has eight trapezoidal steel box girders (or tub girder) units. Each unit has a unique span arrangement and horizontal curvature with a minimum radius of 890 ft. The concrete deck is 8 in. thick and

Austin Bridge & Road

Dual, curved trapezoidal steel box girders connect I-30 and the Eastern Extension of the President George Bush Turnpike near Dallas.

Greg Kochersperger, P.E., is a professional associate with HDR Engineering, Dallas, where he serves as the bridge section manager. He is an active member of the AASHTO/NSBA Task Group 13—Analysis of Steel Structures. He can be reached at **gregory.kochersperger@hdrinc.com**.



▲ Fig. 1: A typical section showing the 5-ft-deep tub girder webs; the depth of the webs helped facilitate inspection.

➤ Fig. 2: Completed tub girder sections were assembled in the fabrication shop, with internal diaphragms and top lateral bracing installed.

28 ft wide and is supported by two tub girders spaced on 14-ft, 6-in. centers. The girder webs are 5 ft deep to facilitate inspection and the webs are 8 ft apart at the top flanges. Webs slope at 4:1 to match precast concrete U-beams, resulting in a 70-in.-wide bottom flange (see Figure 1).

Tub girders on horizontal curves behave fundamentally differently than curved I-girders. I-girders have very little torsional stiffness and require cross frames between the girders to redistribute torsion in the system into shears between the girders in the cross section. Tub girders, on the other hand, have significant torsional stiffness and typically are stable without the need for additional cross frames or diaphragms between the girders. In the completed structure, the torsional stiffness results from the closed section created by the three-sided box and the concrete slab. Prior to the slab hardening, tub girders rely on top flange lateral bracing to form a pseudo-closed section and provide adequate torsional stiffness during erection and slab placement. Intermediate diaphragms are typically provided between multiple tub girders, but only to minimize rotation of the girders during slab placement, not for overall stability. The intermediate diaphragms often are removed after slab placement, although many agencies now prefer to leave them in place. (The intermediate diaphragms on this project were detailed to be left in place.)

Prior to designing the eight separate units, the designers performed an in-depth study of one of the units and developed a consistent design methodology. Items investigated included torsion during slab placement sequence, top flange lateral bracing orientation, the effect of access holes in pier diaphragms and the use of elastomeric bearings. After the initial investigation, the tub girders were designed using MDX, a commercially available 2D grid analysis software package that sizes girder webs and flanges. Miscellaneous girder members, such as top flange lateral bracing and internal and external diaphragms, were designed using hand calculations and in-house design spreadsheets. Although the final calculations were based

Austin Bridge & Road

Fig. 3: The contractor was able to bolt an entire span on the ground and lift it as one girder, eliminating the need for shoring towers.

Austin Bridge & Road

Fig. 4: Steel box straddle bents were introduced to reduce the required spans of the superstructure over I-30.

on the MDX model, extensive 3D finite element analysis was performed to verify the analysis as well as the methodology used for designing the miscellaneous members. By fully vetting the design methodology and detailing on the first unit, the following seven units were designed very efficiently.

The girder sections were assembled in the fabrication shop with internal diaphragms and top lateral bracing installed as shown in Figure 2. Installing these members in the shop created a very stable section that was much easier to handle than a traditional I-girder. In the field, the additional torsional stiffness of the tub girders allows them to be erected without the need for external diaphragms, which greatly reduced the time needed for erection. Figure 3 shows how the contractor was able to bolt an entire span on the ground and lift it as one girder, eliminating the need for shoring towers.

The steel tub girders were supported on large, laminated elastomeric bearings. (The design of these bearings was based on previous research and methodology developed by TxDOT and had proved successful on many other projects around the state.) Although the bearings were rather large—up to 24 in. by 40 in.—they provided significant cost savings compared to conventional high-load, multi-rotational bearings.

Steel Box Straddle Bents

At locations where the direct connectors cross over I-30, the required spans were beyond what could be accommodated economically with steel tub girders alone. At those locations, steel box straddle bents were introduced to reduce the required spans of the superstructure, as shown in Figure 4. Although post-tensioned concrete straddle bents were used elsewhere on the project, the use of steel straddle bents over the main lanes eliminated the need for extended closures of the Interstate. The contractor was able to erect a straddle bent cap, as well as the tub girders on top of it, in a single nighttime closure.

These steel box straddle bents are considered fracture-critical and will require regular inspection. (TxDOT discourages the introduction of new fracture-critical elements on its projects.) The tub girder units on this project are also fracture-critical, but the additional effort to inspect additional elements on the project was deemed acceptable when weighed against the impact of Interstate closures during construction.

Picking Up the Slack

In a state dominated by pre-stressed concrete bridges, the use of structural steel is still an essential part of the bridge engineer's tool box—especially in the case of the PGBT/IH 30 interchange, where it proved the best solution for the long-span connector ramps and minimized construction impact on the traveling public. MSC

Owners

Texas Department of Transportation and North Texas Turnpike Authority

Steel Team

Steel Fabricator

Hirschfeld Industries, San Angelo, Texas (NSBA/AISC Member) (AISC Certified Fabricator)

Structural Engineer

HDR Engineering, Inc., Dallas

General Contractor

Austin Bridge & Road, LP, Irving, Texas

This article provides a preview of some of what the author will present in Session B13 at the World Steel Bridge Symposium, April 18-20 in Dallas. Learn more about the World Steel Bridge Symposium and NASCC: The Steel Conference at www.aisc.org/nascc.

A photographic appreciation of the Mackinac Bridge.

Visiting an Old Friend for the First Time

BY LAWRENCE F. KRUTH, P.E.

WITH A TOTAL LENGTH of five miles, including a suspended portion of 8,614 ft between cable anchorages, the Mackinac Bridge, joining Michigan's upper and lower peninsulas, is among the longest suspension bridges in the world. Its 3,800-ft main suspended span is exceeded in the U.S. only by San Francisco's Golden Gate Bridge (4,200 ft) and the Verrazano-Narrows Bridge (4,260 ft), connecting Staten Island and Brooklyn in New York.

Lawrence F. Kruth, P.E., is vice president of engineering, technology and safety with AISC-member Douglas Steel Fabricating Corporation, Lansing, Mich. The firm also is an AISC-certified erector and fabricator.

Built beginning in 1954 and completed in 1957 by the American Bridge Division of the United States Steel Corporation, the Mackinac Bridge consists of more than 100,000 tons of structural steel. At the peak of construction, more than 3,000 people were employed at the bridge site.

After living in Michigan for more than 25 years, I was given an opportunity last August to make a trip to the top of the south tower of the suspension bridge. It's the kind of offer that is on every engineer's wish list, especially those involved in the steel industry.

Getting to the top of the tower begins at the bridge deck level where you enter through a small access door. The door is no more than a small hatch made from plate hinged and locked to prevent access. Next to the door is the dedication plaque placed by American Bridge in 1955.

After entering the tower, you immediately enter the elevator for a trip to the upper portion of the tower. The elevator originally went nearly to the top of the tower, but no longer goes that high. Installation of new drive motors now restricts vertical travel distance of the elevator. Douglas Steel's field operations manger, David Hannah, held the door as I entered the elevator. (Elevator may be too generous of terminology for this

Larry Kruth

Larry Kruth

Larry Kruth

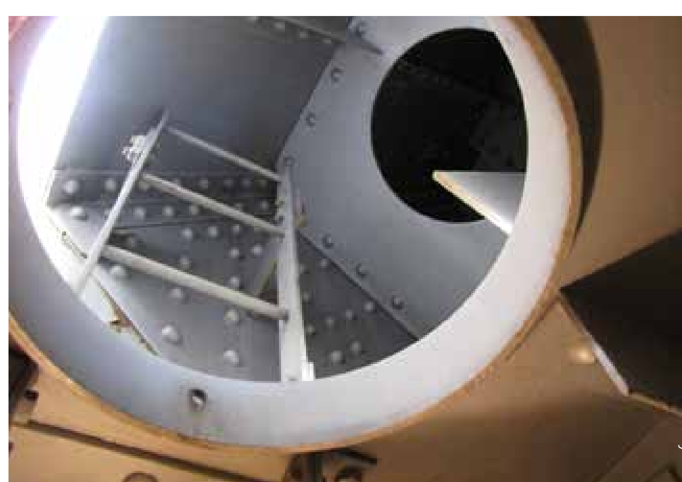
Judd Converse

device, which is approximately half the size of a phone booth.) In addition to Hannah and myself, our guide for the trip also rode with us to the highest vertical access point provided by the elevator.

Upon exiting the elevator we travelled through a series of hatches both horizontal and vertical, climbing up ladders through openings so small that my shoulders would not fit through them without raising my arms over my head. (This reminded me of my tour of the USS Silversides, a World War II submarine anchored in Lake Michigan in Muskegon, Mich.)

Overall the bridge includes 4,851,700 rivets. Traveling through the internal portion of the south tower, I was amazed by the many rivets that were installed in such small areas by the ironworkers back in the 1950s. It also was amazing to see the mill marks on the steel members indicating that U.S. Steel rolled them in my hometown of Pittsburgh. The H-USA marking indicates they were a product of the Homestead Works.

Finally, we came to the vertical access point to the top. To access the top, it was necessary to climb



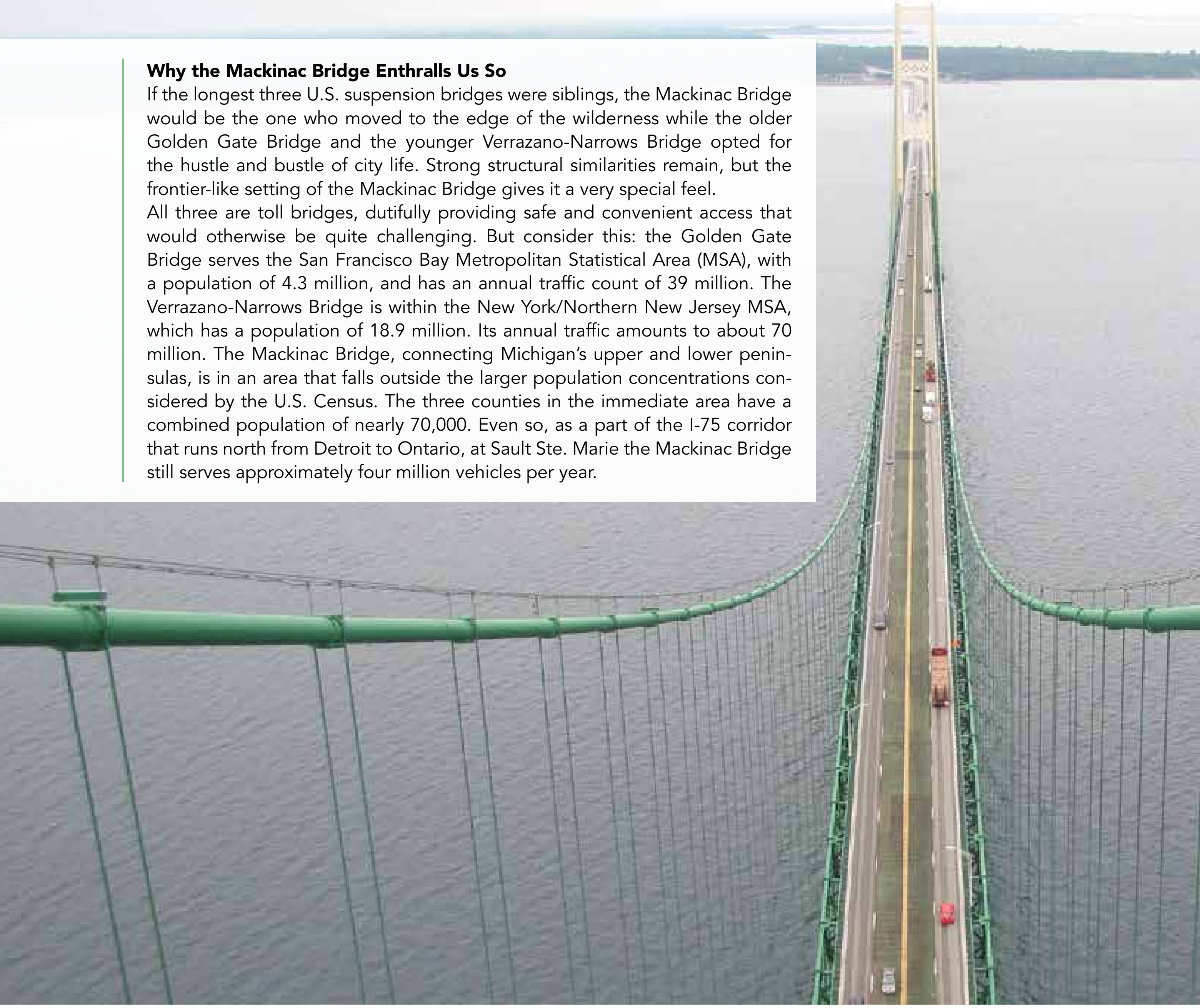
Larry Kruth

Larry Kruth

Why the Mackinac Bridge Enthralls Us So

If the longest three U.S. suspension bridges were siblings, the Mackinac Bridge would be the one who moved to the edge of the wilderness while the older Golden Gate Bridge and the younger Verrazano-Narrows Bridge opted for the hustle and bustle of city life. Strong structural similarities remain, but the frontier-like setting of the Mackinac Bridge gives it a very special feel.

All three are toll bridges, dutifully providing safe and convenient access that would otherwise be quite challenging. But consider this: the Golden Gate Bridge serves the San Francisco Bay Metropolitan Statistical Area (MSA), with a population of 4.3 million, and has an annual traffic count of 39 million. The Verrazano-Narrows Bridge is within the New York/Northern New Jersey MSA, which has a population of 18.9 million. Its annual traffic amounts to about 70 million. The Mackinac Bridge, connecting Michigan's upper and lower peninsulas, is in an area that falls outside the larger population concentrations considered by the U.S. Census. The three counties in the immediate area have a combined population of nearly 70,000. Even so, as a part of the I-75 corridor that runs north from Detroit to Ontario, at Sault Ste. Marie the Mackinac Bridge still serves approximately four million vehicles per year.



Larry Kruth

Judd Converse

Larry Kruth

Judd Converse

Larry Kruth

an unprotected ladder through three very small, round vertical access hatches.

Upon exiting to the top of the south tower, the view made the whole trip worthwhile. The bridge's two towers rise 552 ft above the water level of the Straits of Mackinac. Standing at this location where only a few people had stood before, on a structure that many ironworkers risked their lives to build, was awe-inspiring.

Looking straight down from the tower at this height was breathtaking. The bridge deck consists of two lanes in each direction. The exterior lanes are concrete and the interior lanes are steel grating. The parked red Mackinac Bridge Authority van that took us to the south tower was evident.

As our group explored the area at the top of the tower, we observed many of the fine details of construction. The suspension cables were clearly wrapped with the spinning wire. The saddles for the suspension cables were a marvelous work of engineering and construction. Small angles were mounted to the exterior of the tower to act as anchoring points for the suspended platforms used to paint the tower. The entire Mackinac Bridge is constantly being painted and inspected by the Mackinac Bridge Authority.

Too soon, it was time to leave. I would like to thank the Mackinac Bridge Authority for their hospitality, and also David Hannah, Douglas Steel's field operation manager, and especially Judd Converse, one of Douglas Steel's ironworker foremen, who made it possible for me to cross another item off of my "bucket list." MSC

Larry Kruth

Larry Kruth

Judd Converse

National Steel Bridge Alliance 2012 Prize Bridge Awards

2012 PRIZE BRIDGE AWARD WINNERS

Prize Bridge Awards

- Major Span: Main Street Bridge, Columbus, Ohio
- Long Span: Nooksack River Bridge, Whatcom County, Wash.
- Short Span: South Layton Interchange SPUI at I-15 and Layton Parkway, Layton, Utah
- Movable Span: BSNF Railway Burlington Bridge, Burlington, Iowa
- Reconstructed: I-93 FAST 14 – Salem Street Interchange, Medford, Mass.
- Special Purpose: Tempe Town Lake Pedestrian Bridge, Tempe, Ariz.

Merit Awards

- Major Span: kcICON Project – Christopher S. Bond Bridge, Kansas City, Mo.
- Major Span: John James Audubon Bridge, St. Francisville, La.
- Long Span: Estero Parkway, Estero, Fla.
- Medium Span: S.R. 0113, Section 08B, Gay Street Bridge Replacement Project, Phoenixville, Pa.
- Short Span: Lynch Village Bridge, Lynch Village, Pa.
- Reconstructed: Bridge of Lions Historic Rehabilitation, St. Augustine, Fla.
- Special Purpose: Hillhouse Pedestrian Bridges, New Haven, Conn.
- Special Purpose: Pedestrian Bridge at the Yards Waterfront Park, Washington, D.C.

Accelerated Bridge Construction Commendations

- San Francisco – Oakland Bay Bridge – East Tie-In Structure, San Francisco
- Sam White Bridge, American Fork, Utah
- I-93 FAST 14 – Salem Street Interchange, Medford, Mass.

Sustainability Commendation

- Silverdale Bridge, Stillwater, Minn.

EIGHTEEN STEEL BRIDGES have earned national recognition in the 2012 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 pair of charming New England pedestrian bridges to the longest cable-stayed bridge in the U.S.

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

- Benjamin Beerman, P.E., senior structural engineer, FHWA Resource Center, Atlanta
- Robert Healy, P.E., director of structures, RK&K, Baltimore
- David Hohmann, P.E., senior project manager, HDR Engineering, Austin
- Ray McCabe, P.E., senior vice president, HNTB Corporation, New York
- Hormoz Seradj, P.E., steel bridge standards engineer, Oregon Department of Transportation, Salem, Ore.
- Doug Waltemath, project manager, Harrington & Cortelyou, A Burns & McDonnell Co., Kansas City

This year's competition attracted nearly 70 entries and included a variety of bridge structure types and construction methods. All structures were required to have opened to traffic between May 1, 2009 and September 30, 2011.

The competition started 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.

Prize Bridge Award—Major Span

MAIN STREET BRIDGE, COLUMBUS, OHIO

Columbus, Ohio's original Main Street Bridge, a concrete open spandrel barrel arch that was built over the Scioto River in 1937, was deemed significant enough to make the National Historic Register. By 2002, however, the city found it to be in very poor condition and thus closed it, eliminating the primary connection between the Franklinton neighborhood and downtown. The city knew a new bridge would encourage and facilitate much needed redevelopment for Franklinton, as well as reconnect it to the central business district in time for Columbus' 2012 Bicentennial Celebration.

The replacement span, a steel-framed 663-ft-long structure (including approaches) that opened in 2010, pays homage to the original structure. It also reinforces Columbus' reputation as the "city of arches," employing an inclined arch with clean, classical lines that compliments the city's neighboring art deco buildings and is compatible with other bridges on the waterfront.

The original design of the new bridge was a slender, single-ribbed inclined concrete arch bridge that met all of the city's requirements—with the exception of the budget. This prompted a redesign, in steel, that would retain the key design elements of a sloping, single-ribbed arch, the L-strut braces and separate pedestrian and vehicular decks. The result is the United States' first inclined steel arch bridge tied with cables and struts, that has separate pedestrian and vehicular decks. Inclined at a 10° angle from vertical, the arch emerges through the bridge deck, and steel hangers descend from the arch to support members below the deck. Unlike traditional tied-arch bridges, stay cables are used for the tie. The structure uses nearly 3,000 tons of Grade 50 steel and was designed to last more than a century as the iconic gateway to the heart of Ohio's Capital City.

The bridge features three vehicle lanes for traffic (two eastbound and one westbound), a 5-ft-wide sidewalk on the south side, a steel box girder roadway, piers that complement the superstructure design and a concrete pedestrian deck that sweeps horizontally and vertically away from the roadway to provide an unobstructed view of the city's downtown skyline. Everything in the bridge design is asymmetrical. The inclusion of a separate deck for pedestrians and cyclists emphasizes their importance and provides them with a link to the recently completed Scioto Mile green space project.

More than just a river crossing, this project connects communities with the downtown core, links new parkway developments on both riverbanks, serves as an iconic destination for residents and visitors and provides significant aesthetic value to the city's infrastructure.

Owner
City of Columbus

Designer
HNTB Corporation, Kansas City, Mo.

General Contractor
Kokosing Construction, Columbus

Consulting Firm
DLZ Ohio, Inc., Columbus

Steel Team

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

Cathy Morrison, MoDOT

Tom Skinner, MoDOT

P-Tn.com

Merit Award—Major Span

kcICON PROJECT—CHRISTOPHER S. BOND BRIDGE, KANSAS CITY, MO.

A lot can happen in four miles. Just ask the Missouri Department of Transportation (MoDOT), whose kcICON project involved an overhaul of more than four miles of Interstate 29/35 in Kansas City and North Kansas City, Mo. The $232 million project included the reconstruction of a four-lane section of I-29/I-35, reconfiguring existing lanes and five interchanges, reconstructing 12 bridges and designing and building a landmark bridge over the Missouri River.

This latter component is the 1,700-ft-long Christopher S. Bond Bridge, a two-span, cable-stayed structure that enhances the skyline with its diamond-shaped pylon and semi-fan stay arrangement that rises 300 ft off the water and creates a striking gateway experience for motorists. The superstructure is supported by 40 stays that radiate in a semi-fan arrangement from a single diamond-shaped pylon of reinforced concrete. The suspended portion of the bridge consists of an asymmetrical composite steel and concrete system with a main span of 550 ft and a side span of 451.5 ft. The cross section of the bridge deck includes three 12-ft traffic lanes in each direction along with a 12-ft northbound auxiliary lane. The bridge features a kinetic lighting system with diode panels mounted to the edge girders to allow an infinite number of lighting shows across the length of the bridge, from simple one-color panels to complex color-changing events.

The steel framing system comprises two continuous longitudinal edge girders supported by two planes of cable stays. The transverse floor beams are spaced 16 ft, 8 in. apart. At the deck level, the cable stays are anchored by anchor pipes, and the gusset plates are welded directly to the top flanges of the edge girders along the line of the girder webs. This simple concept for connecting the cable gussets to the top flanges of the girders has been successfully implemented on many cable-stayed bridges, but this detail was subject to stringent quality criteria on the Christopher S. Bond Bridge, ensuring trouble-free, long-term durability. These criteria included the following:

- The use of high-quality Z-steel, which is steel with a low sulfur content and a tested level of ductility through the z-axis of the plate to provide for superior strength, ductility and toughness, particularly against high loads acting in a direction perpendicular to the plate surface.
- The successful completion of the wholly nondestructive testing of all welds connecting top flanges to cable gussets.
- The use of a high-quality replaceable sealant where the cable gusset meets the deck to preclude the possibility of crevice corrosion after the infill concrete shrinks.
- The use of a high-performance paint system involving three coats.

The cable stays are anchored, in their semifan arrangement, as closely together as possible at the top of the pylon. This arrangement minimizes the amount of bending applied to the pylon by the stays. It also maximizes the cables' vertical angles, allowing for efficient stay sizes and minimizing the axial loads applied to the deck. The cable stays are protected from corrosion in three ways. Each stay is a bundle of seven wire strands, and each strand has wedge anchorages and is sheathed in polyethylene, providing one layer of protection. The interstices within each sheathed strand are filled with a corrosion-inhibiting compound, forming a second barrier. For the third barrier, the entire bundle of strands is enclosed in a high-density polyethylene pipe, forming a corrosion and mechanical protection system.

Owner
Missouri Dept. of Transportation

Designer
Parsons Corporation, Chicago

Architect
Touchstone Architecture & Consulting, P.A., Tallahassee, Fla.

General Contractor
Paseo Corridor Constructors, Kansas City, Mo.

Steel Team

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

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

Merit Award—Major Span

JOHN JAMES AUDUBON BRIDGE, ST. FRANCISVILLE, LA.

Sometimes, records are broken not because they are set to be broken but rather due to circumstances. The John James Audubon Bridge, part of Louisiana's Transportation Infrastructure Model for Economic Development (TIMED) program, spans the Mississippi River near St. Francisville, La. and enhances the economy of the region by providing a means to transport goods across the river in an area where crossings are sparse. The bridge's cable-stayed unit was required to be designed for a minimum span of 1,400 ft across the Mississippi. Due to the shallower depth of water on the east side of the east pier, however, this span was increased to 1,583 ft, making it the longest cable-stayed span in the U.S. This increase facilitated the construction of the east pier in the swift-moving water of the river, while maintaining the overall economy of the proposed solution. The foundations of the towers are supported on 21 drilled shafts, each 8 ft in diameter. This innovation was proposed in lieu of the sunken caisson approach, which is more common for bridges across the lower Mississippi. The drilled shafts reduced the risks associated with delivering, placing and lowering a caisson.

While the 6,505 tons of structural steel used in the project was intended primarily to support vehicular traffic, it also provides a safe river crossing for another community: Louisiana black bears. The project included a total of 10 bear crossings, which double as drainage structures at high-water levels. Fencing is used to provide open areas for the bears to cross, and tunnels were constructed under the roadway for the bears to travel through and to provide a continuous cross-river habitat.

Owner

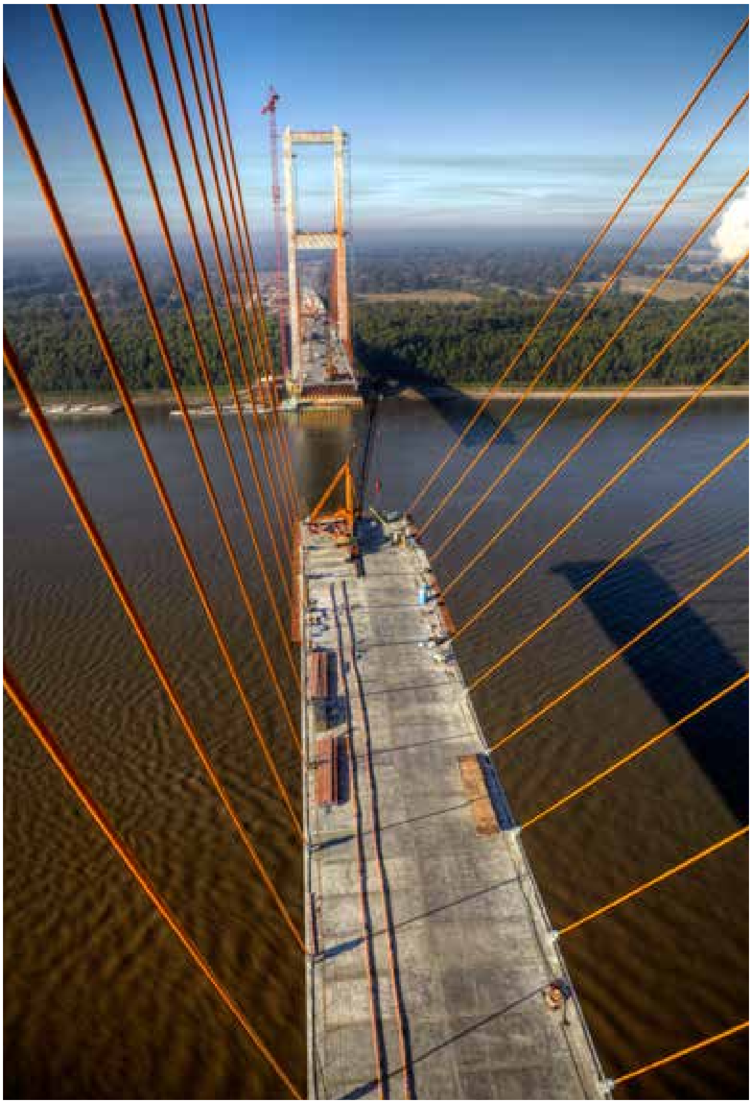
Louisiana Dept. of Transportation and Development

Designers

Parsons Corporation, Baltimore, Md. (Lead Designer)

Buckland & Taylor Ltd. (Designer of Cable-Stayed Main Bridge), North Vancouver, British Columbia

All photos in this spread courtesy of Parsons



General Contractor
Audubon Bridge Constructors (a joint venture of Flatiron Constructors, Granite Construction and Parsons Transportation Group), Benicia, Calif.

Consulting Firm
Louisiana Timed Managers, Baton Rouge, La.

Architect
Touchstone Architecture & Consulting, P.A., Tallahassee, Fla.

Wind Consultant
RWDI, Guelph, Ontario

Steel Team

Steel Fabricator (levee spans)
Stupp Bridge Company, St. Louis (AISC Member/ NSBA Member/AISC Certified Fabricator)

Prize Bridge Award—Long Span

NOOKSACK RIVER BRIDGE, WHATCOM COUNTY, WASH.

Photos this page courtesy of Washington State DOT

While the construction method was left to the contractor's discretion, the single-span truss design used for the Nooksack River Bridge was pre-engineered for cantilevered construction. This approach kept all bridge construction activities outside of the ordinary high-water mark, which not only protected the aquatic ecosystem but also shaved months off the schedule that would have otherwise been incurred to acquire the environmental permits needed for in-water work. In addition, this time-savings allowed for the Washington Department of Transportation (WSDOT) to keep its commitment to the public and have the corridor open in time for the 2010 Winter Olympics in nearby Vancouver.

"Out of the water and way ahead of schedule" is an apt descriptor for the Nooksack River Bridge. Located near Lynden, Wash., approximately six miles south of the border crossing to Canada, the 590-ft-long bridge (total steel tonnage was 700) was part of a widening project—from one lane each way to a four-lane divided highway—for Washington State Route 539.

The cantilevered construction method required two halves of the main span to be temporarily anchored to the precast-prestressed girder approach spans as they were erected piece-by-piece. The anchorage included cable stays supporting a temporary tower frame, which was bolted to the portal panel. Mobile cranes operated on temporary access decking to erect the members. Once the trusses were joined, the access decking was removed and the permanent floor system was installed. (For more on the Nooksack River Bridge, see "The Cantilever Truss Shortcut" in the December 2009 issue of *MSC*.)

Owner/Designer

Washington State Dept. of Transportation

General Contractor

Max. J. Kuney Construction, Spokane, Wash.

Steel Team

Steel Fabricator

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

Steel Detailer

Pro Draft Inc., Surrey, British Columbia (AISC Member/NSBA Member)

Merit Award—Long Span

ESTERO PARKWAY, ESTERO, FLA.

The Estero Parkway project in Estero, Fla. came out on top in a couple of ways—and not just because it's a highway overpass. The 559-ft-long flyover employs the largest tub girders (16 of them) ever erected in the state of Florida. In addition, the average site delivery weighed more than 300 tons and was 380 ft long, making these shipments some of the heaviest hauls to ever travel on Florida roads.

Built to alleviate traffic in the growing Ft. Meyers area and provide a new passage over Interstate 75, the overpass uses a total of 2,278 tons of structural steel and is more than 116 ft wide. Transportation of the girders, which are 15 ft tall and 10 ft wide at the bottom, from Tampa to Ft. Meyers could only be done during four-hour windows, between midnight and 4 a.m. For more on the Estero Parkway project, see "On Opposite Coasts" in the June 2008 issue of *MSC*.)

Photos this page courtesy of V & M Erectors, Inc.

Owner
Lee County Dept. of Transportation, Ft. Meyers, Fla.

Designer
Finley Engineering Group, Tallahassee, Fla.

General Contractor
Zep Construction, Inc., Ft. Myers, Fla.

Consultant
JCA Engineering LLC, Pembroke Pines, Fla.

Steel Team

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

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

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

Merit Award—Medium Span

GAY STREET BRIDGE REPLACEMENT PROJECT, PHOENIXVILLE, PA.

The purpose of the Gay Street Bridge Replacement Project? Simple. Replace an existing 12-span, 936-ft-long concrete arch structure (built in 1924 but that had since deteriorated into poor condition) with a structurally sound bridge with an increased load carrying capacity that would maintain safe and adequate pedestrian, vehicular and emergency services movement over French Creek, Taylor Alley, Mill Street, the Norfolk Southern Railway, the proposed French Creek Parkway and the former site of the Phoenix Iron Works—a brownfield site with proposed future development—between the downtown area of Phoenixville, Pa. and the north side of the community. Oh, and also pay respect to not only the existing structure but also a structure, in the same spot, that predated it.

The new Gay Street Bridge consists of three sections. The first section is the south approach, a three-span continuous composite curved steel plate girder bridge with spans of 61 ft, 61 ft and 75 ft; the south approach and part of the first arch span are located on a horizontal curve. The second section is the north approach, which is a two-span continuous composite steel plate girder bridge with spans of 123 ft, 3 in. and 100 ft. The third (main) section is a four-span arch that uses a two-hinged steel open-spandrel deck arch with a floor system that consists of rolled beam stringers and floor beams; the arch rib is a constant-depth steel plate girder. The span lengths of the arch spans are 116 ft, 162 ft, 162 ft and 112 ft, 3 in. The structure's overall length is 972 ft, 6 in. and its out-to-out width is 50 ft, 2 in., with two sidewalks and bump-outs for lighting and scenic overlooks at each pier. The overlooks provide room for viewing the bridge-mounted historic markers and the site below without interfering with pedestrian movement.

The project was completed approximately three months ahead of schedule (total construction duration was 23 months) and opened to traffic in October of 2009. The arch erection required the use of three cranes to erect each arch rib before the top deck could be put into place. A template plate was used to hold the anchor bolts in place when the piers were poured, simplifying the erection of the arches over the anchor bolts. Deck construction was relatively straightforward, with the exception of the fascia overhangs; the fascia stringers in the arch spans required both tension and compression struts to resist the torsion loads placed on them by the bridge overhang formwork.

The project faced an interesting challenge due to the fact that the existing structure was a contributing element to the extensive Phoenixville Historic District. This bridge was a very prominent fixture in Phoenixville, known locally as the "High Bridge," and many members of the community were passionate about it. Therefore, it was imperative for the design team to work with the community and the Pennsylvania Historic and Museum Commission (PHMC) to provide a context-sensitive design and to define parameters that would be acceptable for the proposed solution. This project also spanned over the former site of the Phoenix Iron Works, which started as a nail factory and then went on to manufacture such items as the Griffen cannon, iron and steel beams and even the patented Phoenix column truss bridges. Now a brownfield site, this property was under land development at the commencement of the replacement project. The only remaining building from the Iron Works facility was the Foundry Building, which was also undergoing a historic renovation during the project.

The design team researched the history of the site to help define the appearance of the new structure, as well as what the material should be. While the existing structure was a massive concrete arch, the previous structure at this location was, in fact, a steel bridge—and since this structure spanned over a site that previously housed a steel fabricator, there was equal support for either a concrete or steel structure. JMT prepared a study that evaluated numerous replacement alternatives that would satisfy the mitigation requirements. Photographic renderings of the replacement alternatives were prepared, a visual preference survey was conducted at a public meeting and a consensus was formed to sustain

Mark Richard of JMT

Paul S. Bartholomew Photography

the history of the site—and to pursue a steel-arch structure. The bridge typical section is highly visible from underneath the new structure. Therefore, the view from underneath was considered as aesthetically important as the elevation view, an issue that played heavily in the decision to provide a true arch span as opposed to a standard beam bridge with arched fascia panels.

Owner
Pennsylvania Dept. of Transportation District 6-0, King of Prussia

Designer
Johnson, Mirmiran & Thompson, Inc. (JMT), York, Pa.

General Contractor
Nyleve Bridge Corporation, Emmaus, Pa.

Steel Team

Steel Fabricator
High Steel Structures, Inc. Lancaster, Pa. (AISC Member/NSBA Member/AISC Certified Fabricator/AISC Advanced Certified Erector)

Steel Detailer
abs Structural Corp., Mellbourne, Fla. (AISC Member)

Photos this page courtesy of Michael Baker Jr., Inc.

Prize Bridge Award—Short Span

SOUTH LAYTON INTERCHANGE, LAYTON, UTAH

The Single Point Urban Interchange (SPUI) was designed as part of the $97M South Layton Interchange project for the Utah Department of Transportation (UDOT). The interchange, over Interstate 15, is an hourglass-shaped 218-ft-long two-span bridge with out-to-out deck widths of 220 ft at abutments and 135 ft at the center bent. It has two 12-ft-wide traffic lanes and a 15-ft-wide turn lane in each direction, an 8-ft-wide sidewalk and 17-ft-wide shoulder on one side, and a 9-ft-wide bike lane and 13-ft, 9-in.-wide shoulder on the other side. The cross-section consists of 12 steel plate girders at 11 ft, 8 in. spacing and six flared girders per span with a 9-in.-thick cast-in-place lightweight concrete deck. The hourglass design reduced material costs substantially as well as satisfied the seismic requirements.

As with many interchange projects, time was of the essence. With only a short six-hour closure window, the team would need to use temporary fill to make up the required grade changes for using self-propelled modular transporters (SPMTs) and then remove the fill to resume interstate traffic. Therefore, a launch technique was designed such that the bridge could still be constructed off-site (allowing the bridge and the new fill to be constructed and placed at the same time) and then moved into place with minimal impacts to traffic. The team accomplished this by launching two sections of the bridge from both sides onto temporary slide support members; once launched, the sections came together in the middle to form the complete bridge structure. This project represents the first ABC multi-span bridge launch in Utah.

In order to accelerate the settlement of the new, tall approach embankments of the bridge, the embankments were temporarily surcharged with 12 ft of soil above the proposed finished grade. Approximately 13 ft of settlement occurred, which was anticipated. During the four months of surcharge settlement time, the team constructed the bridge superstructure on temporary steel supports above the temporary soil surcharges.

The temporary steel supports were constructed by extending the permanent abutment piles at the front end and providing temporary piles at the back end. The slide support members for the launch were two rows of temporary support beams on piles constructed on either side of the three lanes of traffic in each span. After soil settlement was obtained the surcharge was removed from underneath, and after the team raised the superstructure (using 12 lowering jack towers for each span) the temporary structure was removed. The bridge was lowered to approximately 18 ft in about 16 hours and was set on elastomeric pads with Teflon sliding surfaces placed over inverted slide shoes at the forward end, and skid beams at the rear end.

In preparation for the bridge launch, a 3D model was created and a finite-element analysis was performed to calculate the exact deflection of the bridge as it was cantilevered across the interstate. To perform the launch, 22-ft-long launch noses were attached to six of the twelve girders, and the bridge was pushed using hydraulic jacks across Teflon-coated bearing pads located at abutments and intermediate temporary supports. The bridge was then launched into place using hydraulic jacks to push the bridge. The sliding surfaces consisted of Elastomer pads with Teflon surfaces, mounted on inverted stainless steel shoes at abutments, and intermediate temporary supports. These temporary supports were approximately 45 ft apart. The bridge was moved into place using only five hours of the allotted six-hour full lane closures of I-15 in each direction. Each span weighed approximately 1,150 tons (structure, deck, etc.); the steel for the project totalled 410 tons.

Owner
Utah Dept. of Transportation, Salt Lake City

Designer
Michael Baker Jr., Inc., Midvale, Utah

Consultant
Nordholm Rentals (Norsar, LLC), Everett, Wash.

Aesthetics Designer and General Contractor
Ralph L. Wadsworth Construction Company, Inc., Draper, Utah

Steel Team

Steel Fabricator
Utah Pacific Bridge & Steel, Lindon, Utah (AISC Member/NSBA Member/AISC Certified Fabricator)

Merit Award—Short Span

LYNCH VILLAGE BRIDGE, LYNCH VILLAGE, PA.

Lynch Village, Pa. (about 10 miles north of Marienville, Pa.) isn't a large town but it can boast an engineering first. Located on the edge of the Allegheny National Forest in western Pennsylvania, the town is home to a first-of-its-kind, two-span demonstration bridge that carries S.R. 1003 over Tionesta Creek. The bridge uses concrete-filled tubular flange girders (CFTFGs) and its design and construction was the culmination of research and development sponsored by the Federal Highway Administration (FHWA), Pennsylvania Department of Transportation (PennDOT) and the Pennsylvania Infrastructure Technology Alliance (PITA).

A CFTFG is an I-shaped girder that uses a concrete-filled hollow structural section as the top flange. The resulting I-girder section has torsional stiffness and lateral torsional buckling strength that is much larger than that of a conventional steel I-girder with similar depth, width and steel weight. The increased stability and strength allows the lateral bracing of CFTFGs to be minimized, compared to conventional steel I-girders.

This demonstration bridge combined the use of CFTFGs with span-by-span construction to further increase the speed of the steel erection. The girders were designed to be simply supported on temporary erection bearings during deck placement and then made continuous for superimposed dead load and live load. A bolted mechanical field splice is placed at the interior support to make the spans continuous.

The demonstration bridge consists of two 100-ft spans and the overall length is 200 ft from the centerline of the abutment, bearing-to-bearing on a tangent alignment and straight grade. It consists of two 11-ft-wide lanes and two 3-ft-wide shoulders, and uses standard PennDOT barriers (1 ft, 8 in. wide and 2 ft, 8 in. high along each overhang) for an overall structure width of 31 ft, 4 in. and a curb-to-curb width of 28 ft. The bridge cross section has four CFTFGs spaced at 8 ft, 5.5-in centers, with 3-ft deck overhangs.

CFTFGs bring several advantages, including the ability to minimize the required under-clearance, simplify erection and eliminate cross frames or diaphragms. The hollow structural section (HSS) flange is filled with unreinforced concrete in the fabrication shop after girder fabrication, and the concrete strengthens the compression flange of the girder. The torsional stiffness and strength of the girder is significantly increased by the tube, thus increasing the lateral-torsional buckling resistance of the girder. The concrete-filled tube also has the effect of reducing the depth of web in compression, thus decreasing the girder's web slenderness.

This increased stability and strength of a CFTFG allows the lateral bracing to be reduced, compared to that of conventional plate girders, and to span greater distances with the same structure depth. The increase in torsional stiffness and strength also eliminates the need for fabricating exterior girders with intermediate constructability stiffeners, as is needed on normal plate girders to resist overhang forces. Diaphragms or cross-frame and stiffeners are among the most labor-intensive and expensive components per pound of steel to fabricate and erect; therefore, using fewer diaphragms and stiffeners reduces cost and increases speed of construction. A few transverse stiffeners along the girder length are necessary to control cross-section distortion, allowing the girder to fully realize its lateral torsional buckling strength.

On the flip side, this demonstration project revealed that considerable difficulty can arise when attempting to make the tubular flange girders continuous by splicing at the piers. Future designs should consider elimination of the shear connectors within the splice region and incorporate methods that may eliminate the need for the tedious procedures required to set temporary bearings utilizing brackets, as was done on this project. Nevertheless, the project paved the way for future development of steel bridge systems and provides an additional option to engineer.

Owner

Pennsylvania Dept. of Transportation

Designer

Michael Baker Jr., Inc., Moon Township, Pa.

Other

Lehigh University Department of Civil and Environmental Engineering, Bethlehem, Pa.

General Contractor

Francis J. Palo, Inc., Clarion, Pa.

Steel Team

Steel Fabricator

High Steel Structures, Inc., Lancaster, Pa. (AISC Member/NSBA Member/AISC Certified Fabricator/AISC Advanced Certified Erector)

Photos this page courtesy of Michael Baker Jr., Inc.

Prize Bridge Award – Movable Span

BSNF RAILWAY BURLINGTON BRIDGE, BURLINGTON, IOWA

The reconstruction of the century-old BNSF Burlington Bridge over the Mississippi River at Burlington, Iowa began in 1991 when the United States Coast Guard issued an Order to Alter under the Truman Hobbs Act for replacement of the swing span. The bridge was a hazard to river traffic due to the narrow navigable width of approximately 160 ft on either side of the center pivot pier. The replacement structure needed to provide a minimum 300 ft of horizontal channel clearance and 60 ft of vertical clearance above the normal pool elevation.

This directive to replace the existing swing span led designer HNTB Corporation to study various alternate designs and alignments, thus leading to the selection of a vertical lift span to replace the swing span on the existing alignment. Nearly two decades after the Order was issued—and following preliminary studies and design and final design of project—replacement of the swing span commenced in 2009, with a portion of the federal funding provided through the American Recovery and Reinvestment Act of 2009.

During construction of the replacement span, not one, not two but nine flood events occurred. In fact, out of the 680 days from notice to proceed to substantial completion, 143 days were at or above the flood stage and a total of 192 days were lost due to unseasonably high river elevations. While other items, such as the lift span erection on barges, could continue during flood events, critical path substructure was delayed.

HNTB's railroad experts were on call throughout the project, and participated in design review meetings on site, allowing for construction issues to be addressed ahead of time to keep the project moving forward. In an effort to reduce construction cost, BNSF researched their inventory for secondhand deck plate girder spans that could fill the gap left following removal of Span 6. Six individual spans were needed, four at 80 ft in length and two at 93 ft, each span supporting one track. BNSF was able to locate four 80-ft, two-girder spans that could be reused with minimal rehabilitative work (in an effort to minimize the environmental footprint, HNTB reused as much of the existing structure as possible, including the existing bridge

HNTB

HNTB

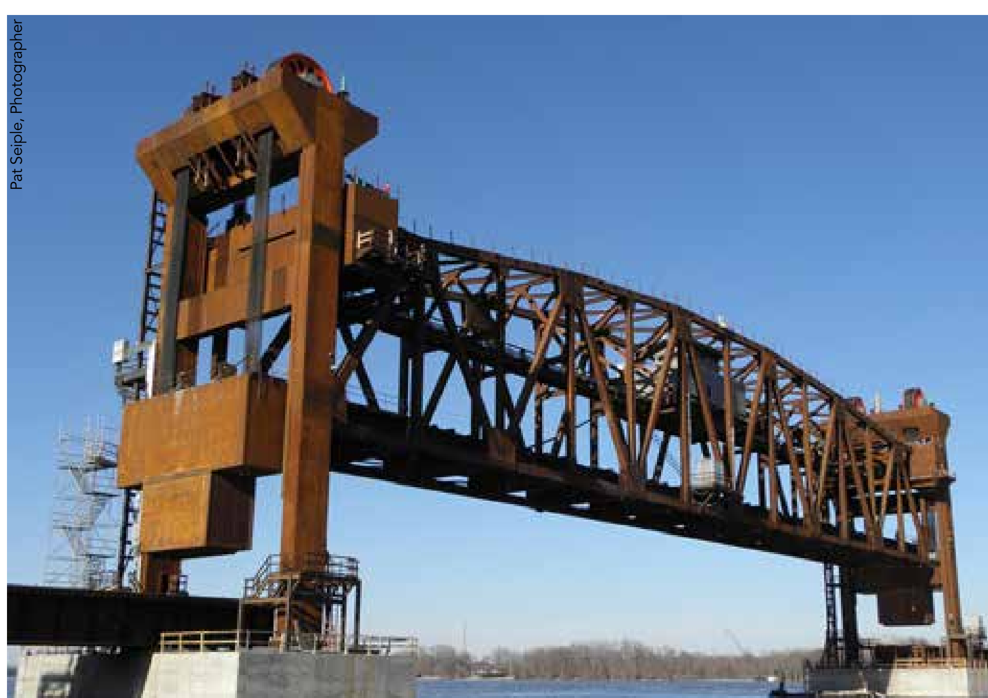
Matt McDonald, Photographer

piers). The spans were shipped to the BRT Staging Yard as individual girders and a new cross frame system was installed on-site. The 93-ft deck plate girder spans were designed by HNTB and were constructed of new material. The spans consisted of four deck plate girders with internal cross framing. These spans were also erected on site and stored until needed.

Owner
BNSF Railway Company

Designer
HNTB Corporation, Kansas City, Mo.

General Contractor
Ames Construction, Burnsville, Minn.



Pat Seiple, Photographer

Photos in this page courtesy of CME Associates, Inc.

Prize Bridge Award—Reconstructed Accelerated Bridge Construction Commendation

I-93 FAST 14—SALEM STREET INTERCHANGE, MEDFORD, MASS.

The Salem Street bridge carries Interstate 93 over Salem Street westbound in Medford, Mass. and is part of a rotary interchange that contains two similar bridges: I-93 over Salem Street WB and I-93 over Salem Street EB. All of these bridges were part of the "93 Fast 14" project, which replaced 14 I-93 bridges in 10 weekends last year.

I-93 is an eight-lane elevated expressway that carries approximately 200,000 vehicles per day. The 14 bridges in the 93 Fast 14 project all carry I-93 over local features such as city streets, state highways and the Mystic River. All of the bridges are steel stringer spans with concrete decks. Thirteen of the fourteen bridges are multiple span structures. The entire superstructures would be replaced due to deterioration of the concrete decks and the beam ends (brought on by years of leaking deck joints).

During the summer of 2010, MassDOT was exploring the feasibility of replacing bridge superstructures on I-93 in Medford using accelerated bridge construction (ABC) techniques. In August, while the feasibility study was underway, a failure of one of the bridge decks occurred during an ongoing resurfacing project. A large "punch-through" developed on the bridge that carries I-93 over Route 28. The ensuing repair required the removal of hundreds of square feet of deteriorated concrete. The severe traffic impacts that occurred as a result of the deck failure affected the entire Metro Boston area and drove home the point that ABC methods would be needed to maintain mobility during bridge construction activities. It also underscored the need to begin and complete the deck replacement project before more potholes developed. Spurred by the punch-through, MassDOT accelerated the project so that construction would be complete in 2011, with all the superstructure replacements occurring between June 1 and September 4, 2011.

Central to the ABC process were the prefabricated modular beam units used on the project. Each unit is made of two grade 50 weathering steel girders pre-topped with a composite deck. By using modular units for the superstructure, the construction team was able to demolish and replace the Salem Street Bridge in less than 55 hours. The 55-hour window occurred during a weekend so that rush hour traffic was not impacted by construction—a very important aspect of this project, since it is located on a major artery just outside of Boston. The units were shipped to the project site and placed side-by-side to form the new bridge superstructure and were connected using a simple cast-in-place concrete closure pour. The spans were designed and detailed as simple spans. However, using link slab technology, the completed decks are jointless. In addition, no special equipment was needed for construction; each unit was erected using standard high-capacity hydraulic cranes. The closure pours between the units allowed for significant adjustment in the field in order to accommodate the variations in the 50-year-old substructures. In addition to the accelerated construction techniques, the fabrication and delivery of steel was also expedited. The first set of bridge units was delivered in only four months (including deck casting). All 252 units (504 girders) for all bridges in the 93 Fast 14 project were fabricated in fewer than six months.

Owner
Massachusetts Dept. of Transportation

Designer
Gill Engineering Associates, Needham, Mass.

General Contractor
White-Kiewit J.V., Framingham, Mass.

Steel Team
Steel Fabricator/Detailer
Structal Bridges, A division of Canam Steel Corporation, Point of Rocks, Md. (AISC Member/NSBA Member/ AISC Certified Fabricator)

Sub-consultant
CME Associates, Inc. (concept development/owners rep.), East Hartford, Conn.; Dewberry, Boston, Mass.; Lin Associates, Inc., Brighton, Mass.; Tensor Engineering (sub-consultant detailer), Indian Harbour Beach, Fla. (AISC Member/NSBA Member)

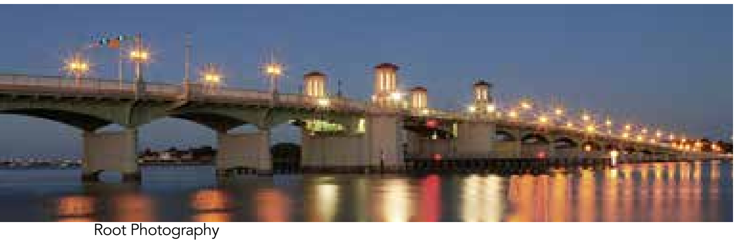
Merit Award—Reconstructed

BRIDGE OF LIONS HISTORIC REHABILITATION, ST. AUGUSTINE, FLA.

The historic Bridge of Lions has long been one of the most recognizable structures in St. Augustine, Fla. Originally built in 1927 and listed in the National Register of Historic Places, the bridge serves as a critical link between Anastasia Island and St. Augustine's historic downtown area. Over the years, however, the bridge showed signs of significant deterioration and was in need of safety improvements, leading the Florida Department of Transportation (FDOT) to rehabilitate the historic structure.

Following *The Secretary of Interior's Standards for Rehabilitation*, the reconstruction project's design team sought to preserve as much of the original bridge as possible, while also improving safety and transportation connectivity. Maintaining the steel arched girders of the approach spans (as well as the bascule piers and towers, built in the Mediterranean-Revival style architecture of many of the historic buildings in downtown St. Augustine) was crucial. However, the bridge did not meet modern load carrying capacity (the original 15-ton posted limit was less than the weight of the city's largest fire truck). Preserving these elements required a key innovation: a one-of-a-kind interior steel framework and a new foundation system.

In order to increase load carrying capacity, the team designed a new interior steel framing system that would be hidden from view and essentially constitute a new bridge within the existing 1927 structure. The original framing system consisted of two non-redundant, parallel plate girders spaced 22 ft. apart transversely. These riveted, built-up girders were typically continuous over two piers with a shear splice at mid-span in the first and third spans of each unit. Transverse steel floor beams were spaced 7 ft, 5 in. apart perpendicular to and framed between the two main girders. These floor beams transferred dead and live loads from the bridge deck to discrete points along the length of the two girders; thus the two girders ultimately carried the entire load of the bridge.


Root Photography


Root Photography

The new interior framing system replaced the existing transverse floor beams with a longitudinal stringer system parallel to the main girders. The stringers then shifted the main loads of the bridge to transverse crossbeams at each pier support, allowing the original girders to be removed, repaired and returned to the bridge without having to carry the entire load as they had done for nearly 80 years. The new interior framing system also allows higher fatigue ranges, but more importantly eliminates the longitudinal fracture-critical non-redundant two-girder system.

Construction began in 2005 and lasted six years, as the Bridge of Lions was completely dismantled only to be rebuilt again, this time stronger, while also preserving as many of the original elements as possible. To maintain traffic during the rehabilitation, the team also designed and constructed a 1,600-ft temporary bridge, which included a vertical lift-span designed to 80-ft vertical clearance. (This bridge was removed once the original bridge reopened.)

Owner
Florida Dept. of Transportation

Designer
Reynolds, Smith and Hills, Inc. (RS&H), South Jacksonville, Fla.

Architect
Kenneth Smith Architects, Inc., Jacksonville, Fla.

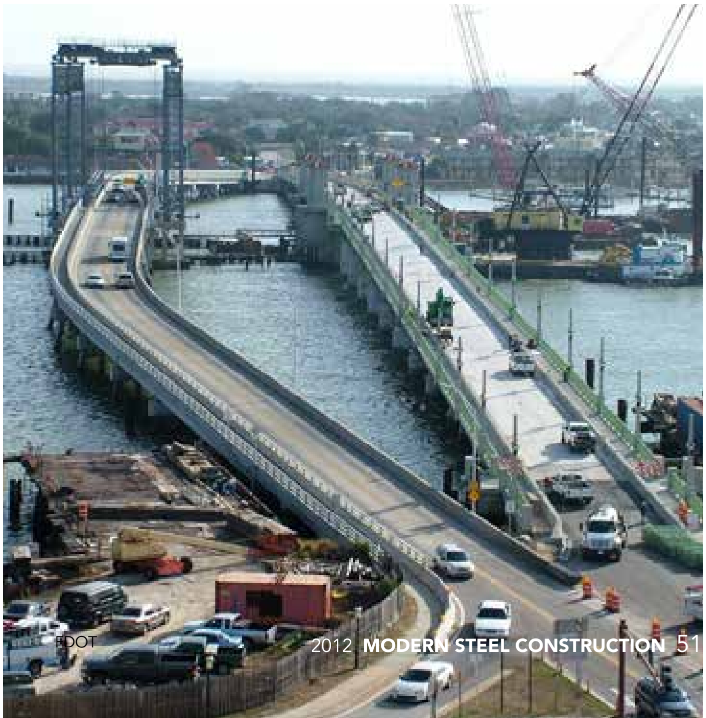
General Contractor
Skanska USA Civil, Virginia Beach, Va.

Steel Team

Steel Fabricator
Florida Structural Steel, Tampa, Fla. (AISC Member/NSBA Member/AISC Certified Fabricator)

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

Other
TranSystems, Ft. Lauderdale, Fla.
Taylor Engineering, Inc., Jacksonville, Fla.
MACTEC, Jacksonville, Fla.
Halback Design Group, Inc., St. Augustine, Fla.


FDOT

Prize Bridge Award – Special Purpose

TEMPE TOWN LAKE PEDESTRIAN BRIDGE, TEMPE, ARIZ.

Photos this page courtesy of T.Y. Lin International

The Tempe Town Lake Pedestrian Bridge was designed to provide both function and aesthetics to the Tempe Town Lake area. It connects existing bike and pedestrian paths from the north and south sides of the lake, allowing runners, walkers and bikers to cross the lake without having to compete with vehicular traffic at major intersections.

The inspiration for the design came from the natural and built environments of Tempe Town Lake and Rio Salado area. The graceful curves of the arches recall the undulating Salt River and the crossing of the arches and suspension cables create geometric shapes echoing the architectural patterns found in the Tempe Center for the Arts. Crossing of the arches creates a distinctive shadow on the bridge deck that is commemorated in a paving band, which marks the shadow on the summer solstice. The shade structures between each arch evoke the wings of a crane in flight and subtle lighting enhances the romantic nighttime atmosphere of Tempe Town Lake.

The total structure length is 912 ft from abutment to abutment and consists of four simple-span tied arches that are each 225 ft, 8 in. Each span is integrated with the existing Tempe Town Lake Dam's concrete piers and abutments for its foundation. The bottom chords and arches are fabricated from 16-in.-diameter HSS. The tubular steel pipe varies in thickness from 0.375 in. to 0.844 in. The bottom chords are spaced at 20 ft on center and serve as the anchor point for the 34-ft-high arches, which slope at 21.4°, leaning and crossing each other near the quarter points, giving the bridge its distinctive shape. Structural steel hangers (1⅜-in.-diameter galvanized cables) are positioned at the 10th points of the bottom chord and attached to offsetting points at the top chord, causing the cables to cross one another both within the plane of each arch and in the locations where the arches have crossed. The floor system is supported by W12×53 floor beams and W12×40 stringers.

Transporting the completed HSS frame of the bridge in one piece was not feasible, so sections were delivered to a fit-up area immediately west of the Tempe Dam and assembled. The bottom chords of each span were shipped in thirds already framed with the associated floor beams and stringers, then set on 12 equally spaced pre-leveled field stands. Each arch was delivered in five pieces. Two falsework towers were built and set at the quarter point locations, and saddles were used to prop all legs in place while a crane positioned the remaining top arch section in-place. Precise fit-up of the whole arch was crucial, as any offset of a connection would have an impact on the integrity of the structure. Once the steel frame was completed, the steel hangers were placed and tensioned according to the detailed sequencing and specifications to provide rigidity to the structure.

Owner
City of Tempe

Designer
T.Y. Lin International, Tempe, Ariz.

Architect
Otak, Tempe, Ariz.

General Contractor
PCL Constructors, Tempe, Ariz.

Project Artist
Willco Art and Design, Tempe, Ariz.

Merit Award—Special Purpose

HILLHOUSE PEDESTRIAN BRIDGES

The Hillhouse Avenue area, listed on the National Register of Historic Places and part of Yale's University's New Haven, Conn. campus, has been called a walkable museum, due to its 19th century mansions and streetscape. Mark Twain and Charles Dickens both called Hillhouse Avenue "the most beautiful street in America." Seen from a distance, the two new Hillhouse Avenue pedestrian bridges that span the Farmington Canal trail resemble a 19th century-style lattice truss bridge. It is a modern twist on a truss bridge design, patented in 1820 by New Haven architect Ithiel Town, who resided on Hillhouse Avenue.

The current Hillhouse Avenue improvement plan was to construct two pedestrian bridges, in addition to replacing the motor vehicle bridge. When the vehicular bridge was reconstructed, the pedestrian passageways were separated as two independent footbridges to align with the existing axes of the sidewalks along the avenue. The two bridges are identical apart from their widths; the east bridge has a clear width of 10 ft while the west bridge has a clear width of 8 ft. The bridges span 62 ft clear and are made from a high-performance, high-strength steel (HPS70W). Each one consists of two 46-in. deep steel plate girders that comprise the primary structure, as well as the handrails.

While unimaginable when Ithiel Town designed his truss, the team used a series of 3D computer analyses to design and verify the capacity of its most prominent feature: the undulating wave pattern of the railings. In addition to establishing the

Matthew Butts

prominent aesthetic feature of the bridges, the railings function as the principal load-carrying members in the half-through girder bridge. While girders with constant web corrugation have been developed and used in highway bridges for more than a decade, the design team varied the amplitudes of the waves to accommodate the changing structural demands of each bridge across its span. The girder web sections with the greatest corrugation amplitudes are located at the bridge ends, where the corrugation enhances the shear capacity of the ¼-in.-thick web, and at midspan, where the corrugated web laterally braces the top compression flange of the girder.

In between, where deep corrugation is not required, the amplitude of the wave is reduced. This direct relationship between the form of the bridge and its structural function results in a more efficient design, including reduced web plate thickness and elimination of web stiffeners. The plate girders have ¼-in.-thick corrugated, perforated webs and are, in fact, the first of their kind. (Although corrugated webs have been used previously on highway bridges, the new bridges at Yale are believed to be the first in the world to combine a corrugated design with perforations.) Because the use of corrugation to stiffen the webs was a relatively new concept, the team also had to validate the approach, including evaluating and confirming research conducted at Lehigh University on corrugated web girders. The research indicated that the welded connections between the bottom flanges were of paramount importance because of the complex stresses that could develop in those locations as a result of the shear loading on the corrugated geometry of the welds.

Each bridge was installed on-site in a single lift. The four bearings on each bridge, located below each girder end, allow for both longitudinal and transverse expansion and contraction due to the extreme temperature changes in the area.

Steven Wolfe

Owner
Yale University & City of New Haven

Designer
Guy Nordenson and Associates, New York

Architect
Pelli Clarke Pelli, New Haven, Conn.

Steel Team

Steel Fabricator
Michelman-Cancelliere IronWorks, Inc., Lehigh Valley, Pa. (AISC Member/NSBA Member/AISC Certified Fabricator)

Sure Iron Works, Brooklyn, N.Y. (AISC Member)

Robert Silman Associates

Robert Silman Associates

Merit Award—Special Purpose

PEDESTRIAN BRIDGE AT THE YARDS WATERFRONT PARK, WASHINGTON, D.C.

This 200-foot pedestrian bridge is a striking centerpiece in the new Yards Park on the Anacostia riverfront in Washington, D.C. This park is at the center of the on-going redevelopment and restoration of a long-abandoned portion of the historic Navy Yard, and links Nationals Park (home of MLB's Washington Nationals) with the remaining Anacostia waterfront restoration project.

The bridge has a dramatic curved, sweeping geometry that creates a feeling of compression and release as one walks through its circular rings from one side to the other. The tied-arch structure features built-up steel box elements with an arch depth of 8 ft. The tension tie element is a 14-in.-deep member, with the slab and beam deck cast between to maintain the thin profile. The arches sweep inward so that the bridge deck compresses from 18 ft wide at the abutments to about ten ft wide at the center. The arches also cant inward, and are braced by rings of varying radii, giving the bridge an hourglass form. These rings are rolled 8-in.-diameter HSS members; below the top chord, they are reinforced by a series of built-up plates, with fixity to the transverse deck girders to provide moment continuity around the completed rings. It is this continuity between the rings and the deck that provides bracing for the arch compression members. The desired aesthetic is a feeling of lightness of the ribs as they extended above the top chord.

However, the behavior of the structure's form works against this. The canted orientation of the top chord means that the rings attract a significant amount of the out-of-plane load for bracing the compression arch. This was solved through staging of the steel erection. By leaving out the top section of the ribs until after the arches were erected and the concrete deck was placed, the lateral forces from the top chord, due dead load, were carried by the continuity of the rings to the deck girders. For analysis of this intermediate stage, the bridge assumed a half-through truss (or "pony truss") configuration, wherein the compression chords were elastically braced by the lower portion of the ribs and the transverse framing in the bridge deck. With most of the permanent load locked into the lower structure and the stability of the compression chords provided for by the bottom of the rings, the remaining top segment of the ribs could be installed, only to see forces imposed by live loads.

The greatest design challenge for this bridge was balancing the flow of forces through the structure while satisfying the aesthetically driven form. While the primary structural elements of this bridge are the pair of tied arches, the ribs exhibit significant vierendeel behavior, forming a hybrid structure similar to many covered timber bridges. As the ribs were stiffened to resist forces transverse to the arches and to ensure the top chord's stability, the ribs attracted more moment in the plane of the arch. This required a carefully coordinated effort to satisfy the desired aesthetic of each built-up rib section, while maintaining stresses within the strength and fatigue limits.

Owner
Forest City Washington, Washington, D.C.

Designer
Robert Silman Associates, Washington, D.C.

Architect
MPFP LLC/M. Paul Friedberg & Partners, New York

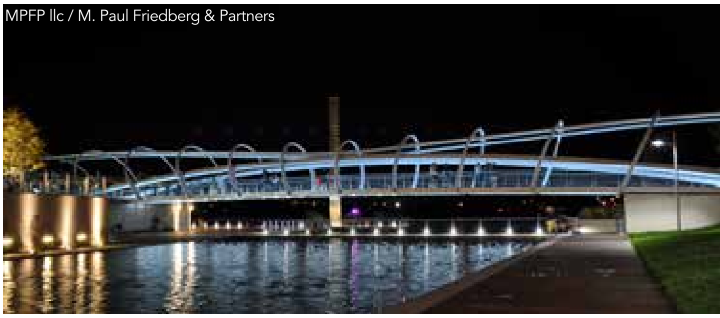
General Contractor
Smoot Construction/P. J. Dick Incorporated Joint Venture, Washington, D.C.

Steel Team

Steel Fabricators
Banker Steel Company, Lynchburg, Va. (AISC Member/NSBA Member/AISC Certified Fabricator)

Steel Detailer
WSP Mountain Enterprises, Sharpsburg, Md. (AISC Member)

Steel Erector
Williams Steel Erection Co., Inc., Manassas, Va. (AISC Member/NSBA Member/AISC Advanced Certified Erector)



MPFP llc / M. Paul Friedberg & Partners

MPFP llc / M. Paul Friedberg & Partners

Photos this page courtesy of Barrie Rokeach for T.Y. Lin International

Accelerated Bridge Construction Commendation

SAN FRANCISCO-OAKLAND BAY BRIDGE—EAST TIE-IN STRUCTURE

The average person might not realize that the San Francisco-Oakland Bay Bridge is really one giant bridge made up of several smaller sections. One such section is the East Tie-In (ETI) structure, a double decked, steel truss bridge. Over Labor Day weekend in 2009, the Bay Bridge was closed so that a section of the existing bridge could be removed and a new section, which acts as a detour for traffic connecting Yerba Buena Island (YBI) to the existing eastern span of the Bay Bridge, could be brought in—a method of construction called roll-out/roll-in (RORI).

The RORI operation is very rarely executed because of the challenges involved, but the rewards can be equally significant; the project has expedited the completion of the East Span Replacement by as much as two years, providing a significant cost savings to the region and the State. Additionally, the project dramatically improves the seismic safety of the current structure by replacing structures that currently do not meet today's seismic standards. In addition, a lengthy bridge closure was avoided and the impact of construction to the public was reduced to a mere four days.

The main challenge was to connect the detour structure with the existing east spans with minimum interruption to traffic. The closure to traffic was limited to a four-day weekend, during which crews removed an existing 288-ft-long span by rolling it sideways to the north, and rolled in a new truss, thus redirecting the traffic from the existing bridge spans to the detour structure. The existing truss was 70 years old and weighed approximately 3,300 tons, and what complicated the operation was that the structure sat 150 ft above ground level. The truss was originally designed to sit on its bearings and not for jacking-up at the intermediate nodes.

The available capacity needed for the modified load path was investigated and the truss was then strengthened where required. The new truss was positioned south of the existing alignment, ready to be rolled in; this meant erecting the new truss on temporary supports 150 ft in the air! The rolling system had to be robust and reliable; it had to be able to withstand the vagaries of Bay Area's weather. Given the tight schedule, CalTrans and the design team opted to use a bridge information modeling (BrIM) approach to render the new ETI structures during the design phase. The models were used to perform a virtual simulation of the construction sequence and to evaluate the procedures and systems employed for the RORI operation to identify and eliminate all possible geometry and space requirement issues.

The most challenging aspect of the entire operation was the removal of the old truss because of the uncertainty involved with the forces locked in during the original erection of the truss (decades ago) as well as the instability of the remaining trusses once the roll-out truss was disconnected from the bridge and rolled out. There are a total of four trusses, each 288 ft long, on YBI leading to the island's tunnel. The two trusses next to the main cantilever truss over the old navigation channel are tied into a massive concrete pier designated E1, which also serves as a tension tie-down for the cantilever truss. The other two trusses are also tied into concrete pier located towards the entrance to the tunnel portal. Once the roll-out truss was removed, there was the risk that the adjacent truss might become unstable. However, this was addressed by designing tension ties to the remaining trusses on the tunnel side.

Owner
California Dept. of Transportation

Designer
T.Y. Lin International/Moffatt & Nichol Joint Venture, San Francisco

General Contractor
C. C. Myers, Inc., Rancho Cordova, Calif.

Steel Team

Steel Fabricator
Thompson Metal Fab, Inc., Vancouver, Wash. (AISC Member/NSBA Member/AISC Certified Fabricator)

Steel Detailer
Norcal Structural, Berkeley, Calif. (AISC Member/NSBA Member)

Other
Mammoet (Jacking/Moving)

SAM WHITE BRIDGE, AMERICAN FORK, UTAH

Photos this page courtesy of Provo River Constructors

In March of 2011, bridge history was made in American Fork, Utah, when the Sam White Bridge over Interstate 15 was moved in one night. It is the longest two-span bridge ever moved by SPMTs in the Western Hemisphere. Crews set the bridge into place at approximately 4 a.m. on a Sunday and reopened the freeway at 7 a.m., three hours ahead of schedule (the entire move took 6½ hours). Two sets of SPMTs—hydraulic jacks on wheels, controlled by a single joystick—were used to lift the 354-ft-long, 3.8 million-lb structure 21 ft in the air. The bridge was then moved from the "bridge farm," where it was constructed on the east side of I-15, across eight freeway lanes (approximately 500 ft) and lowered into place.

The bridge itself is a two-span steel-plate girder structure and is 76 ft, 10 in. long. The superstructure uses six girders at 13 ft, 6 in. spacing with a 4 ft, 8-in. overhang. The girders use 70-ksi steel in the flanges over the bent and 50-ksi steel everywhere else. The framing plan uses staggered perpendicular cross frames up to near the bent. Near the bent the cross frames go to a continuous line across the bent, with each line intersecting the girder at the column. The bent does not have a cap; each girder sits directly on a 4-ft-sq. column.

Constructing the bridge using SPMTs helps meet the project's aggressive three-year timeline. The bridge is one of 59 bridges that are expected to be new, rebuilt or modified on UDOT's I-15 CORE project by December 2012.

The Sam White Bridge is UDOT's 23rd ABC bridge move—nearly double the number moved by all other states combined. The FHWA designated UDOT's move as a "showcase" event for leaders to learn more about ABC technology and how it can be applied to other transportation systems in the country.

Owner
Utah Dept. of Transportation

Designer
Michael Baker Jr., Midvale, Utah

General Contractor
Provo River Constructors, Lehi, Utah

Other
The Sarens Group, Rigging International, Missoula, Mont.

Steel Team

Steel Fabricator
Utah Pacific Bridge & Steel, Pleasant Grove, Utah (AISC Member/NSBA Member/AISC Certified Fabricator)

Sustainability Commendation

SILVERDALE BRIDGE, STILLWATER, MINN.

Sometime in the 1870s, the Silverdale Bridge started life as an equestrian and footbridge over a river in Sauk Centre, Minn. In 1937, it was disassembled and moved near Silverdale, Minn. to serve as a vehicular bridge over the Little Fork River. And in 2009, it was dismantled for refurbishment, moved near Stillwater, Minn. and since late last year is back its original duties as an equestrian bridge, as it carries horses and riders on the Gateway Trail over a roadway.

Aligned on a north-south axis, the crossing consists of a 162-ft, wrought-iron eight-panel pin-connected Parker through truss with three steel-beam approach spans on the north and three on the south. The superstructure rests on H-piling abutments and timber piers and bents. In the main span, the two truss webs are identically detailed. Paired channel sections with V-lacing form the upper chord, while paired punched eyebars comprise the lower chord. All vertical members are double paired angle sections with V-lacing.

When it came to rehabilitating the bridge, given that the original plans weren't available, 3D laser-scanning technology was used to evaluate the structure. This created a "point cloud" of the bridge, consisting of 13 million points, each with x, y and z coordinates. The point cloud, a geometrically correct digital representation of a structure that can be viewed from any angle, assisted greatly in the fabrication of replacement members. Only two of the nine floor beams required replacement, though a new floor system was installed, due to corrosion of the vintage steel stringers (caused by drainage through the timber deck, which was replaced with a lightweight concrete deck).

Who knows what's in store for the bridge in its fourth life, but thanks to this most recent rehab, that shouldn't be a concern for quite some time.

For more on the Silverdale Bridge, see "Back on the Job" in the January 2012 issue of *MSC*. MSC

Co-Owners
Minnesota Dept. of Transportation
Minnesota Dept. of Natural Resources, St. Paul, Minn.

Designer
HNTB Corporation, Bloomington, Minn.

General Contractor
Minnowa Construction, Harmony, Minn.

Consulting Firm
Olson & Nesvold Engineers, P.S.C., Bloomington, Minn.

Cost Consultant
A.A. Sehlin Consultants, Naples, Fla.

Coatings Consultant
KTA-Tator, Inc., Pittsburgh, Pa.

Steel Team
Steel Fabricator/Detailer
White Oak Metals, Inc., Dalton, Minn. (AISC Member/NSBA Member/AISC Certified Fabricator)

Olson & Nesvold Engineers

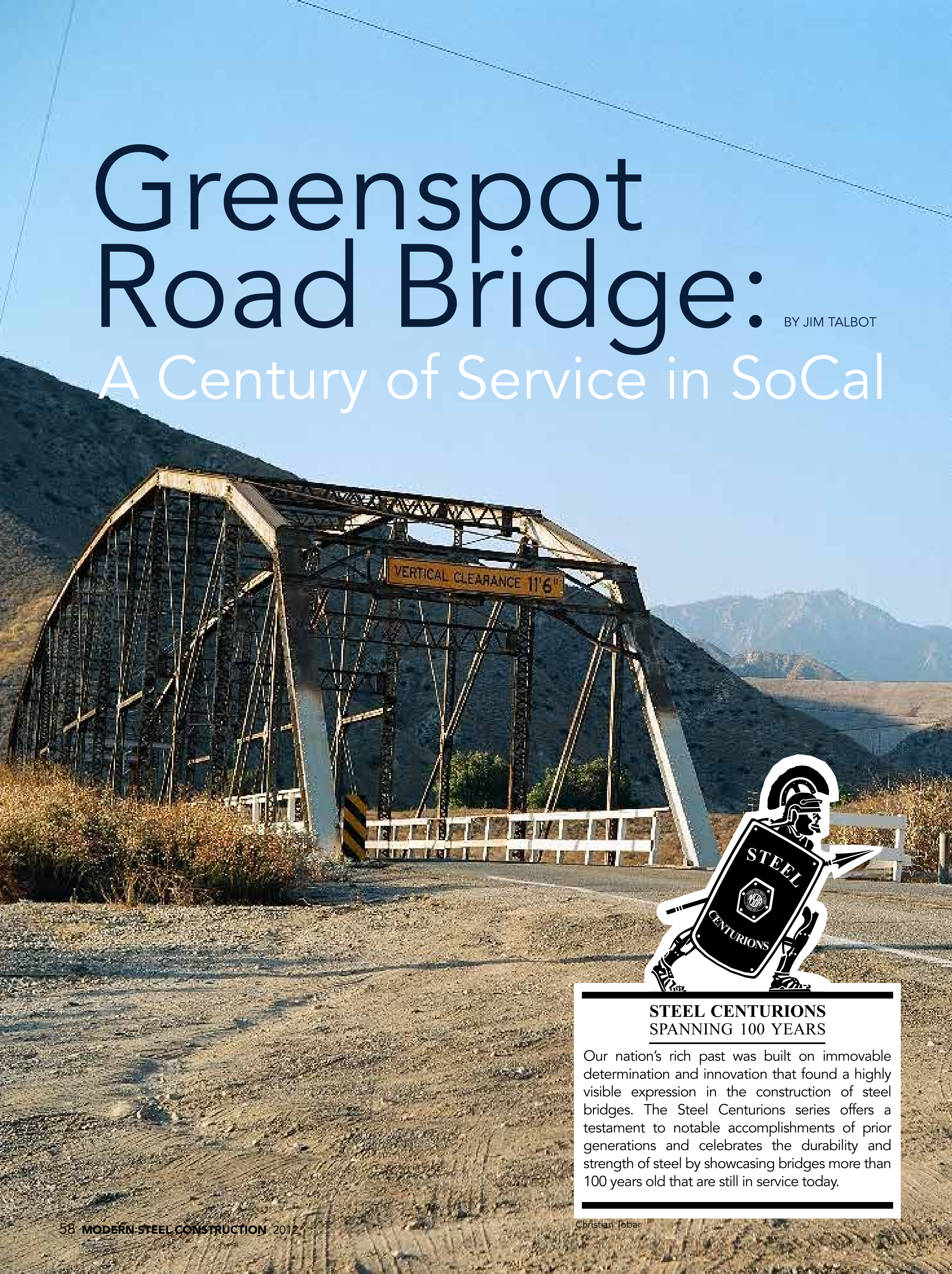
Olson & Nesvold Engineers

Tim Davis/HNTB

Tim Davis/HNTB

Greenspot Road Bridge: A Century of Service in SoCal

BY JIM TALBOT



Christian Tobar

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.

One of the nation's few remaining Pennsylvania truss bridges still carries traffic, but is slated for conversion as part of a trail for cyclists, horseback riders and hikers.

IF YOU DRIVE DUE EAST from Los Angeles, following the route of historic Route 66 (now decommisioned), you'll eventually be on Foothill Boulevard, California State Road 66.

Near San Bernardino, SR 66 continues as 5th Street. The old US 66 turned north near I 215, eventually reaching Chicago, while today 5th Street continues east. After 5th Street passes Rt 210, it becomes Greenspot Road. This old two-lane road continues east along the wide wash of the Santa Ana River. It winds through orange groves, headed for the San Bernardino Mountains. Near the mountains it suddenly turns south to cross the river toward the towns of Mentone and Redlands.

The crossing is the site of the Greenspot Road Bridge, our latest Centurion steel bridge, built in 1912. This historic pin-connected, 14-panel Pennsylvania through-truss steel bridge (which uses approximately 200 tons of steel) takes Greenspot Road across the river, where it flows out of the San Bernardino Mountains and into the San Bernardino Valley. Citrus, grapes and other agricultural crops flourished on both sides of the river early in the 20th century (in 1911, for example, San Bernardino held the first National Orange Show), and the bridge may have been built in anticipation of tolls for transporting nearby crops to rail terminals.

Upstream, the river moves quickly through mountain canyons, historically famous for the mining of gold, silver, copper and other metals. Before the river reaches the bridge, however, it enters the wide, flat bed of the valley. The area near the bridge, boulder-strewn and sun-bleached, often experiences summer temperatures above 100° F.

The Penn Truss

The Pennsylvania truss design has similarities to a Pratt truss, with diagonals sloping away from the center. In this particular bridge, the vertical members are double-paired angle sections with V-lacing. V-laced lateral sections also brace the top chords, which also consist of laced channels. Two pairs of punched eye bars serve as the bottom chords. The vertical and diagonal members meet at the ends of the eye bars. Steel cross beams at these interconnections support the four steel stringers below the wood deck.

Many of the diagonals between verticals are augmented with half-length vertical, horizontal and diagonal struts and ties—a defining characteristic of the Pennsylvania truss design. Gusset plates steady the interconnections. The Pennsylvania Railroad pioneered the design, making it popular for hundreds of bridges in the United States early in the 20th century. Few remain.

The asphalt-covered wood deck of the Greenspot Road Bridge has a width of only 16.7 ft, marginally sufficient for two lanes. Drivers familiar with the bridge usually wait for opposing traffic to clear the bridge to avoid losing a side-view mirror. A white-painted railing lines both sides of the roadway. Deformations of the metal superstructure have resulted from traffic collisions, and the bridge is classified as structurally deficient.

Stampings on the steel identify the manufacturer as the Cambria Steel Company from Johnstown, Pa., which also built the bridge. This company started up in the mid-1850s as the Cambria Iron Works, and the company's beginnings coincided with the arrival of the Pennsylvania Railroad into Johnstown. In 1916, the Midvale Steel and Ordnance Company bought Cambria Steel, and several years later sold it to Bethlehem Steel.

Despite its condition, the 255-ft-long bridge still serves as a vital local link for more than 35,000 people who live in neighboring Highland to the north and Mentone to the south. The bridge sees traffic of about 3,500 vehicles daily (many motorists use it to avoid Interstate 10). Plans are underway to widen Greenspot Road and to rehabilitate the bridge as a crossing for the Santa Ana River Crest-to-Coast Trail for hikers and horseback riders; the project is still awaiting full funding. A replacement bridge for vehicular traffic will be built nearby (to the west) when more funds become available.

Today, the area surrounding the Greenspot Road Bridge consists of wide river bottom and floodplain terraces and falls within the Santa Ana River Wash Land Management and Habitat Conservation Plan area, an area of 4,365 acres of river and its surrounding floodplain that is set aside for conservation and recreation. And this Centurion is a significant component of it. MSC

Jim Talbot is a freelance technical writer living in Ambler, Pa.

bridge crossings

ALL TOGETHER NOW

BY MICHAEL A. GRUBB, P.E., AND DANN H. HALL

While bridge superstructures and substructures are often designed separately, a holistic design approach can increase the efficiency of both.

THE FOUNDATION to any truly great steel bridge design includes a consistent and economical approach to both the superstructure and the substructure. And while the superstructure and substructure act in concert to form the structure, each is often analyzed for separate loads and isolated from the other as much as possible both physically and analytically—and this can lead to an inefficient steel design.

Efficiency can be improved if the substructure and superstructure are compatible with respect to economic, structural and aesthetic demands. When alternate designs are prepared, the substructure for the steel design must be evaluated and designed concurrently with the superstructure. In addition, for cases where the chosen substructure form dictates the use of bearings, consideration should be given to the use of less expensive bearings such as elastomeric ones, where the calculated movements and rotations are within the tolerable limits of these bearings.

Form Follows Function

Bridge substructures are designed to safely transfer lateral loads as well as vertical loads. Some loads are applied directly to the substructure, but most loads are transferred to the substructure from the superstructure through the bearings, shear keys or integrally. While the superstructure generally must resist vertical loads far in excess of lateral loads, the substructure is subjected to a wide range of lateral load effects. As a result, the form of the most efficient substructure must be deduced from its many functions, while remaining consistent with the existing soil conditions.

Michael A. Grubb, P.E., is with M.A. Grubb & Associates, LLC in Wexford, Pa. Dann H. Hall is with Bridge Software Development International, Ltd., a provider of advanced software for the structural analysis and design of steel bridges, in Coopersburg, Pa.

The substructure must be designed according to the specification for various combinations of the force effects. The specification may either provide for increased allowable stresses or call for reduced load factors for each force effect to account for the reduced probability of the individual design forces occurring simultaneously.

Multiple column shafts provide more than one path for the vertical loads to reach the foundation. The total vertical capacity of the substructure is usually greater than the sum of the vertical loads in these cases; thus, the substructure would be designed for more than the total vertical load.

When pile foundations are employed, the objective is to minimize the number of piles. The number of piles cannot be less than the number required to resist the fully factored vertical load. Lateral loads create an increased downward force on some piles, but not an increase in the total vertical force. Therefore, if more piles are required to resist lateral loads than are necessary to resist the vertical loads, it can be hypothesized that an improved substructure design and/or pile arrangement may be possible.

To minimize the number of piles, consideration should be given to employing a single-shaft pier. Single-shaft piers are non-redundant, which may eliminate the need to investigate multiple live-load positions to determine the maximum vertical live load on the pier. The smaller footprint of single-shaft piers may also be advantageous in certain situations, such as when a single-shaft pier might eliminate a skewed pier. Of course the height of the pier, width of bridge and under-clearance dictate the practicality of single-shaft piers, as well as any aesthetic considerations.

Torsional behavior of the superstructure can be used to reduce overturning effects on single-shaft piers. When a single-box cross section is used, the loads on the extreme of the deck are transferred by torsion in the box to the pier by a couple in the reactions. This technique greatly reduces the pier bending by allowing the superstructure to handle the eccentric loads, and is employed to great advantage with single-box segmental concrete bridges. This can also be accomplished with a single steel box or two I-girders with bottom flange lateral bracing.

More typically, the steel superstructure consists of multiple girders supported on single-shaft piers consisting of hammerhead pier caps. Hammerhead pier caps can be designed to be integral with the girders. These are often employed to improve under-clearance. Many skewed piers have been eliminated in this manner. Not only is a long pier minimized, but the skew is also eliminated.

Fixed bearings can distribute load to several piers. Piers integral to the superstructure transmit longitudinal forces, such as ice, to many piers, which can resist the forces in reverse bending (double curvature), reducing the base moment. Integral connection of steel superstructure and substructure is usually not practical, but distribution of longitudinal and transverse forces via fixed bearings to several piers is still economically beneficial. These arrangements of fixed bearings are particularly useful in mitigating thermal forces in longer multi-span bridges. Such designs obviously require consideration of the interaction at design.

Careful treatment of skewed supports permits the design of efficient elastomeric bearings in cases where the computed girder rotations are small enough to be accommodated by such bearings. Lateral forces in the bearings can be immense at skewed supports. They can often be alleviated by judicious selection of bearing releases and constraints. The forces in the end diaphragms can also be reduced to tolerable levels.

Span Optimization

The optimum span arrangement for a steel design is usually different from the optimum span arrangement for a concrete structure. In competitive situations, it is important to optimize spans for both materials when possible. The cost of any additional borings is usually offset by the economy gained. The versatility of steel permits it to be used in span arrangements optimal for concrete. If a single-span arrangement is chosen, it is usually one that is optimal for concrete. An alternate steel design for those spans can be made, but it will not be optimal. Span lengths should preferably be arranged to yield approximately equal maximum positive dead-load moments in the end and center spans. These balanced span arrangements (end spans approximately 80% of interior spans) result in balanced moments and deflections, while reducing the likelihood of uplift in short end spans or inefficient interior spans if the end span is too long. Such span arrangements result in optimal depth of the girder in all spans, with nearly the same moments and deflections and a more efficient and aesthetic design.

In situations where there are severe depth restrictions or where it is desirable to eliminate center piers (e.g., certain overpass-type structures), it may be desirable to provide short end spans. However, in cases where there are no such restrictions, it is often economical to extend the end spans to provide a balanced span ratio, avoiding costs associated with the need for tie-downs at end bearings, inefficient girder depths and additional moment in the interior spans. In curved structures, extension of the end spans may also permit the use of radial supports where skewed supports might have otherwise been necessary. Elimination of skewed abutments and piers reduces the cost of the substructure and reduces the effects of torsion on the superstructure design.

For major, long bridge projects, superstructure and substructure cost curves should be developed for a series of preliminary designs with different spans. Because the concrete deck costs are constant and independent of span length, they need not be considered when developing these curves. The optimum span arrangement lies at the minimum of the sum of the superstructure and substructure costs. These curves should always be regenerated to incorporate changes in unit costs that may result from an improved knowledge of specific site conditions, particularly the pier costs.

The specifications do not limit the length of jointless bridges. Elimination of joints provides savings by reducing or optimizing the number bearings, the cross-frame, expansion devices and less efficient end-spans. By attaching the superstructure to several piers with fixed longitudinally restrained bearings and forcing the piers to flex, less expensive elastomeric fixed bearings often can be used. Longitudinal forces are then distributed to several piers in proportion to their relative stiffnesses. Multiple-span steel girder bridges more than 2,000 ft long, with expansion joints only at their ends, have been successfully built in moderate to cold climates.

Integral and Semi-Integral Abutments

Integral and semi-integral abutments have the characteristic of having no deck-joint at the abutments. This is done to reduce maintenance by reducing the amount of water that enters the abutment area. Integral abutments resist end rotation of the girders and longitudinal force. The restraint of rotation causes negative end moments that must be resisted by the girder connection to the abutment and by the girders. Vertical loads on the girders cause negative end moments in the girders. These moments generate tension in the deck and compression in the bottom flange which may be problematic.

A single row of piles is generally used to increase flexibility. Steel piles, concrete-filled pipe piles and concrete piles have also been employed. There are several ways more flexible piles can be obtained. A sleeve may surround the pile; predrilled piles may be used with granular material surrounding the pile; or fixed base piles may be used. Integral skewed abutments are problematic but have been used. The piles at the acute angle tend to unload, which increases the force on the piles at the obtuse angle. Hence, an increased number of piles are required. The unequal loading on the piles causes restoring shear in the concrete deck and in the connections to the girders. Integral abutments with steel girder bridges up to about 400 ft in length have been successfully constructed.

To extend the span range for bridges without deck joints, some states use a semi-integral abutment concept. In these abutments, elastomeric bearings are typically introduced under the girders to provide a horizontal flexible interface at the bridge seat to separate the superstructure from the abutment and allow rotation of the girders. Semi-integral abutments are easier to construct than fully integral abutments.

Integral abutments introduce issues that may be deleterious to both the substructure and the superstructure. As the bridge attempts to lengthen or shorten due to temperature changes, forces are generated in the abutment and the superstructure. The approach slabs often rest on a polyethylene sheet (or some similar material) to minimize friction. Measurements of the coefficient of friction between the slab and the soil indicate that it varies between 0.9 and 1.9.

A Holistic Approach

Steel is an inherently versatile material and it can be adapted to most any substructure and span arrangement. When the site dictates difficult span arrangements and pier designs, steel is often the only material of choice. However, its efficiency often suffers when designed to conform to foundations developed for other materials. The foundation of a good steel bridge design lies in a holistic approach that encompasses the site demands, aesthetics and economics. **MSC**

This article was originally published in the January 1998 issue of MSC *as No. 13 in a series that is being updated and reissued by the authors and NSBA.*

Early to the Party

BY MARTIN ANDERSON

Using a kit-of-parts approach, the Golden Gate Bridge's welcome center comes together in time for a big birthday bash.

THE GOLDEN GATE BRIDGE is one of the most instantly recognizable bridges in the world—perhaps the most.

And it just turned 75.

On May 27 the Golden Gate Bridge celebrated three-quarters of a century of service to both the thousands of Bay Area commuters who cross and the thousands of tourists who visit it daily. Arriving just in time to help handle the anniversary crowds was a new steel-framed bridge pavilion building at the San Francisco end of the bridge.

Approximately nine million people visit the bridge each year—around twenty-four thousand a day—putting a significant strain on the local facilities. As the 75th anniversary approached, it became clear that the existing visitor facilities would need to be updated and reorganized to handle the ever-increasing flow of people and traffic. A number of site upgrades were need: changing traffic flows for buses, new parking arrangements, renovating the historic Round House facility into an education center and creating an entirely new 3,500-sq.-ft bridge pavilion building to serve as the updated welcome center and museum store.

The request for proposal for the new pavilion was issued in January 2011, with an aggressive project deadline; it would have to pass review by three agencies, as well as successfully complete a Cultural Landscape Report for the California State Historic Preservation Office and still be open and operational by April 2012. Moreover, the entire project would have to minimize the impact to existing traffic and visitor flows. Some disruption would be inevitable, but even so thousands upon thou-

photos this spread by Mariko Reed

sands of people would be passing through the area on a daily basis. Combined with a restricted site butting up against two 2:1 slopes and a 6-ft drop across the building's 100-ft length, it was going to be a challenging project.

Modular Method

To execute these improvements, the Golden Gate National Parks Conservancy (an arm of the National Park Service) partnered with the Golden Gate Bridge Highway and Transportation District, which was created in 1928 to build and operate the Bridge. The task of building the new bridge pavilion was given to Project Frog, a company that has the self-proclaimed goal of revolutionizing the way buildings are created.

Martin Anderson is AISC's Steel Solutions Center information specialist. He can be reached at **anderson@aisc.org**.

The new Bridge Pavilion is one of several site improvements being made at the Golden Gate.

Founded in 2006 with an initial focus on the school market, Project Frog takes a systematic approach to buildings to produce customized structures from carefully standardized components. The company's individual buildings (which are generally single-story) are basically assemblies of options that are fabricated off-site, shipped flat and assembled/erected on-site. This involves a careful balance between taking advantage of prefabrication without shipping unnecessary volumes of empty space, unduly complicating crane lifts, requiring too many truckloads or demanding special hauling.

This approach isn't prefab for the sake of prefab, nor is it traditional modular construction, but is rather more akin to a "kit of parts" that is specifically designed for speed, ease of construction, environmental performance and finished quality. Individual building components (such as wall panels, roof panels, window systems, internal structural supports and so on) are designed from the outset to work with the rest of the system so that they can be combined in many different ways. This lets each building be customized to meet project-specific requirements without sacrificing the speed afforded by component standardization.

Among the advantages of this approach is the ability to rapidly develop shop drawings, since individual parts of the system have their own independent drawings developed in advance. When the building design is finalized, components are picked from the catalog as needed, with their drawings already complete.

In the case of the bridge pavilion, the kit-of-parts approach made it possible to meet the aggressive project schedule; it took less than two months to go from site selection and program development to final design and construction documents. In fact, since the curtain wall and entrance systems had the longest production lead times, shop drawings for those components were approved and released for manufacturing before the final floor elevation was determined.

Similarly, the entire building shell was able to be installed by a four-person crew—three ironworkers and one small crane operator. The structural steel was designed so that all welds were performed in the shop and all field connections were bolted. Insulated metal stud wall panels (painted in International Orange to match the bridge, of course!) were dropped into place by crane, with full adjustability provided by slotted Halfen anchors at the base and a proprietary Unistrut detail at the top.

A Worthwhile Process

The structural steel fabrication and erection were both handled by Ahlborn Structural Steel, Inc., who has provided steel work for several Project Frog buildings and has found the modular process worthwhile.

"One of the most desirable aspects of the structural steel prefab building concept is the option to fill holes in our shop schedule," says Ahlborn's president, Tom Ahlborn. "If we have an opening, we will check with Project Frog on progress on a particular job in their pipeline. On many occasions we have released assemblies for fabrication, trusses, braced frames and the like ahead of the actual job release. These are assemblies we know will not change from job to job, so our only worry is how long they may sit before shipping to paint."

"Further, estimating for these types of buildings is easy since we put in the time up front," he continues. "No two jobs are the same, but we have a master list of assemblies we've priced out with individual weights for HSS, wide-flange and plates, including fit-up requirements, welds, machining and QA/QC times for each."

Ahlborn explains that when Project Frog sends his shop a building package, a complete price is available within a matter of minutes, including a detailed breakdown of the shop hours required. With each package, the shop typically sees a few new assemblies, which are added to its database.

All of this gives the customer their building faster and lets the fabricator run their shop for maximum efficiency. The focus on speed and efficiency extends to BIM, says Ahlborn detailing manager Deric Henderson.

"All Project Frog modular buildings are created and designed in 3D," he explains. "When the project is handed off to us, we import their model into Tekla for checking, troubleshooting and general review. We then send Project Frog an export of our model for them to review, allowing our teams to find and resolve issues long before they become problems. Project Frog and the Ahlborn detailing team work in unison during these projects—not just during production, but also during building creation and design."

The structure opened on May 8 in plenty of time to host the thousands of visitors who came to celebrate the Golden Gate Bridge's 75th birthday on May 27. MSC

Owner
Golden Gate National Parks Conservancy

Architect
Jensen Architects, San Francisco

Building Kit Designer
Project Frog, San Francisco

Structural Engineer
Tipping Mar, Berkeley, Calif.

General Contractor
Fisher Development, Inc.

Steel Team

Fabricator, Erector and Detailer
Ahlborn Structural Steel, Inc., Santa Rosa, Calif. (AISC Member/AISC Certified Fabricator)

Anything but Redundant

BY HONGZHI ZHANG, P.E., PH.D.

A Washington flyover curves through a tight construction window using a non-redundant steel plate girder system.

AS THE WASHINGTON State Department of Transportation (WSDOT) works to mitigate congestion, there is an increasing demand for grade-separated interchanges for the state's highways. Recent large design projects have demonstrated the need for cost-effective, single-lane structures. These structures are being located in previously developed, highly constrained urban settings, requiring long spans, thin superstructure depths and ease of construction over existing traffic.

SR522/US2 Interchange BNSF RR Flyover Ramp, which opened to traffic in December, is one of the ramp structures that was recently designed under such constraints and resulted in the use of a four-span steel-plate-girder bridge. The bridge is 27 ft wide with a total length of 712 ft and crosses over the BNSF Railroad near Monroe, Wash., northeast of Seattle. The main span over the railroad is 230 ft, and two-thirds of the bridge's length is curved with a 300-ft radius.

Because of this sharp curve, lateral instability caused by the torsional moment was a primary concern. A steel box girder was considered first because it is the most efficient structural type for resisting torsional moment. However, that would have meant shipping 120-ft-long, 28-ft-wide loads from the fabricator's facility in Oregon, which was not deemed practical. The alternative of using shorter sections would have increased the number of field splices, making construction both more difficult and more expensive, so that idea also was rejected.

Hongzhi Zhang is a senior design engineer and seismic specialist with the WSDOT/Bridge and Structures Office, where he has worked for more than two decades. He can be reached at **zhangho@wsdot.wa.gov**.

A concrete box girder was also ruled out because of the vertical clearance required over the railroad tracks. The bridge geometry would not have provided adequate space for falsework while allowing the railroad to remain in operation. The huge mass of the concrete box superstructure also would have created challenges for the drilled shaft substructure design of the bridge, which is located in a high seismic zone with the potential for soil liquefaction.

Redundant or not?

A steel plate girder bridge seemed to be the most feasible and cost-effective solution. The only question was how many girders to use. Decades ago, WSDOT defined girder bridges with less than four girders as non-redundant superstructures. In recent years, however, three-girder superstructures have been redefined as redundant superstructures.

In the preliminary design of the flyover ramp, all the piers, including those along the curve, were designed to be perpendicular to the alignment line. As the result of the radial bearings, the main span length of the exterior girder is 235 ft but the interior span is only 223 ft. Structural analysis of the bridge showed that the maximum flexural demand on the exterior girder was much higher than on the interior girder, but the shear demand on the interior girder was much higher than on the exterior one.

This meant that if a three-girder system was selected, it still would not provide complete load path redundancy due to the uneven load distribution resulting from the curvature of the bridge. On the other hand, a four-girder superstructure would provide redundancy but would result in a girder spacing of less than 7 ft, and would therefore not be cost effective.

A structure using two steel plate girders with a 16-ft spacing ended up being selected as the most cost-effective solution. Because a two-plate girder system is classified as fracture critical, due to the lack of structural redundancy, certain welding procedures and bridge inspection rules had to be applied.

In order to reduce the weight of the superstructure and ease the seismic demands on the substructure, the design used a two-way slab to reduce the slab thickness from 10½ in. to 8½ in.,


Hongzhi Zhang

▲ Two cranes hold the curved girder during erection.

The SR522 BNSF Flyover Bridge in November 2011, a month before it opened.

with shear studs installed on the top of the girders and the top of the cross frame members.

In the design of the SR522 RR Flyover, a cross-frame spacing of approximately 15 ft was designed on the curved portion and 25 ft for the straight portion. All cross frames were designed as primary members. Reinforced concrete end diaphragms were installed at both abutments to increase the fixity of the boundary condition and resist uplift on the outside girder, further stabilizing the two-girder system against the torsional moment.

Pinned disc bearings were designed on the intermediate piers to carry the vertical loads and to resist the lateral seismic loads. One-directional movable disc bearings at the end abutments allow free longitudinal movement.

A 3D finite element analysis was performed using GT-STRUDL and the results compared with the results of structural analysis using MDX to ensure correctness and accuracy. The analyses showed that the design of all the girders and the bracing frames met the requirements of the AASHTO *Bridge Design Specifications*.

Tracks and Wires

Constraints in terms of proximity to power lines and railroad tracks also had to be factored in. Two 120-KV power lines, one on each side of the railroad, posed a threat to both the shaft installations and girder erection. Through negotiations with both power line owners, one of the lines was temporarily shut down during construction and the other was rerouted. In addition, the railroad would not allow any temporary supports to be installed within 15 ft of their tracks. The designed field splicing points had to be adjusted to fit these constraints.

Under the circumstances, a "Suggested Girder Erection Plan" was provided on the design plan. This included the footprint of the temporary shoring towers, the locations where cranes should be set up and the calculated girder segment weight between splice points. A special notice was included in the plan, warning the contractor to consider the torsional rotation, warping and the differential vertical deflections between the two girders. The plan also recommended joining the two segments crossing the railroad together and then putting them on temporary support towers because it would be very challenging to anchor just one segment alone on the support towers. Of course, lifting two segments with the connecting cross frames would require a higher capacity crane, and the two segments together might also increase the difficulties of connecting to the other pieces on the temporary support towers simultaneously.

However, if choosing to put one piece at a time on the temporary tower as the alternative method, instead of providing required anchorages, the contractor would utilize one higher capacity crane to lift the segment between field-spliced points, while the other crane would hold the middle point of the segment as long as needed for connecting the adjacent girder segment to the first one with all the cross frames.

Under the dead load of the bridge deck, the curved bridge will not only experience differential vertical deflection between the interior girder and exterior girder, but will also experience the torsional rotation caused by the eccentric dead load. The torsional rotation will change the super elevation of the bridge deck. The cambers of the girders under the dead load of steel only and the dead load of the composite section were calculated and included in a table in the contract plans. But the calculated cambers in the table were based on the final stage of the construction, not for the falsework settings. The falsework settings had to be designed differently in order to match the designed final super elevation after the deck placement. MSC

This project was discussed in the 2012 World Steel Bridge Symposium session "Bridge Potpourri II" (B16). You can watch a video of this session (and others) at ***www.aisc.org/2012nascconline****.*

Owner, Structural Engineer and Architect
Washington State Department of Transportation, Olympia

General Contractor
Scarsella Bros., Inc., Kent, Wash.

Steel Team

Steel Fabricator
Fought and Co., Inc., Tigard, Ore. (AISC Member/AISC Certified Fabricator)

economics

Recent federal-level transportation legislation closes a small loophole—but needs to address the big picture.

LONG-TERM PLAN FOR LONG (AND SHORT) SPANS

BY BRIAN RAFF

AT APPROXIMATELY 4 A.M. on June 28, members of the House and Senate Surface Transportation Conference Committee agreed to and signed a conference report on the Transportation Reauthorization.

In 2005, Congress passed the Safe, Accountable, Flexible, Efficient, Transportation Equity Act – a Legacy for Users (SAFETEA-LU), which expired in 2009. Since then, it has been through a series of nine extensions, and while this reauthorization (the process by which Congress prescribes changes to transportation legislation in order to meet evolving transportation needs) is technically a new bill, NSBA views it as nothing more than another extension to SAFETEA-LU.

The 600-page bill includes funding through Fiscal Year (FY) 2014, at current levels, with a slight increase to adjust for inflation. (For FY 2012, the limitation on federal aid highway program obligations from the Highway Trust Fund is $39.1 billion, increased by the conference report to $39.7 billion in FY 2013 and $40.265 billion in FY 2014.)

In addition to setting future funding levels, the conference report also included language that closes the "segmentation" loophole, which allows a bridge project to be separated into multiple contracts. An example is the self-anchored suspension span portion of the San Francisco – Oakland Bay bridge project. Instead of the entire bridge being treated as one project, it was broken up into nine separate contracts, segmenting the self-anchored suspension span from federal funding and sending its steel procurement and fabrication work to China. This segmentation loophole was never part of Congress' initial intent when writing the Buy America provisions, and the conferees of the Reauthorization effort should be commended for strengthening this provision as well as improving waiver transparency and annual reporting of those waivers. This is an important victory for NSBA and its members, who have been fighting for stronger Buy America provisions since 2004.

A day after the Surface Transportation Conference Committee signed the conference report, the House and Senate passed the negotiated Transportation Reauthorization by wide margins (373 to 52 in the House and 74 to 19 in the Senate). In order to become law, the bill must be "enrolled" and signed by the President, which may have happened by the time you read this article. In order to prevent an expiration of the programs during this process, the House and Senate passed H.R. 6064 (the Temporary Surface Transportation Extension Act of 2012), which extends highway program funding and student loan rates (a component of the completed transportation bill) for one week to allow time for the enrollment process and President's signature.

The good and bad news is that NSBA members will now have approximately two years of predictable, although woefully low, levels of federal funding for highway and bridge projects. It is this current level of inadequate federal transportation funding that has led to construction unemployment to stagnate at 18% and has forced states to tighten their expenditures, focusing more on short-term "patch-and-pave" jobs rather than planning and spending on new major Interstate projects like signature bridges.

In other words, this latest reauthorization is not a long-term bill that will give states enough time to plan large, significant bridge projects. It also doesn't address how the United States will find new sources of transportation funding to improve our infrastructure, but rather continues the use of Band-Aid solutions.

Regardless of funding levels, the domestic bridge industry has ample capacity to fabricate America's signature bridges as well as the myriad of typical highway overpasses and local short spans. In May 2012, NSBA conducted a nationwide study to determine the capacity of our domestic steel bridge fabrication industry. The survey asked U.S. bridge fabricators to state their 2010 plant use as a percentage of their overall capacity. Survey results determined that, on average, our nation's significant steel bridge fabricators only used 67% of their total plant capacity in 2010.

And there are countless examples across the country of what American fabricators have done—and still do. Recent projects such as the new Woodrow Wilson Bridge in Washington, D.C., the Ravenal Bridge in Charleston, S.C. and a new Mississippi River crossing in Louisiana are true success stories from domestic fabricators and their American workers, and our industry is poised to contribute if given the opportunity.

Remember: Just because we have a proverbial "tenth extension" to SAFETEA-LU doesn't mean we are done. It is critical that we continue to educate our legislators on the importance of a long-term, robustly funded transportation bill. If the U.S. is to remain competitive globally, it must promote the efficient movement of freight and commerce in and out of the country, as well as within its borders. The only way to do that is to drastically increase funding for highways and bridges and continue to make transportation a federal priority. MSC

Brian Raff is the marketing director of the National Steel Bridge Alliance. You can reach him at raff@steelbridges.org.

Cal-Berkeley's steel bridge team wins the 21st annual NSSBC.

Golden Moment for Golden Bears

BY GEOFF WEISENBERGER

Photos: Courtesy of Clemson University

THEY TRAVELED FROM ONE COAST to the other for the win.

The University of California, Berkeley took first place in the 21st annual ASCE/AISC National Student Steel Bridge Competition (NSSBC), held Memorial Day weekend at Clemson University, S.C. The team of structural engineering students won with their entry, ApoCALypse. The Massachusetts Institute of Technology team took second place, and third place went to California Polytechnic State University, San Luis Obispo. (Full results, both overall and for each category, are available at **www.nssbc.info/History/2012NSSBCResults.pdf**.)

The win, the second in UC Berkeley's history of competing in the NSSBC, was a miraculous turnaround from their performance last year, when their bridge failed the lateral load test.

"Everyone was motivated and resilient this year after what happened last year," said Sabrina Odah, bridge project manager for the UC Berkeley team. "We didn't let that failure break us. We all had the sense that this was our year."

"I'm proud of this team of hard-working, enthusiastic students who designed and constructed their bridge very smartly and efficiently and had an excellent preparation for the national competition," said Marios Panagiotou, an assistant professor of structural engineering in UC Berkeley's Civil and Environmental Engineering (CEE) department and faculty advisor for the team. "They deserved the best and I am happy they got it."

NSSBC, a joint effort between AISC and the American Society of Civil Engineers, started as a regional competition in the upper Midwest in the mid-1980s and grew into a national competition by 1992. The teams—there were 47 this year, compiled of more than 550 students—are narrowed down from nearly 200 teams.

To reach Clemson, these teams had to be among the best in 18 conference competitions around the country—and even the world, as teams from Canada, Mexico and for the first time, China, were selected for the national competition. They were judged in six categories: construction speed, stiffness, lightness, economy, display and efficiency; the best combined score across all six categories wins. (UC Berkeley took the top spot in two categories: construction speed and economy.) Every year, the design parameters change slightly to meet the Problem Statement, which this year was to design and build a new bridge to provide vehicle access to a lodge, as well as to support utilities under the deck; clearance under the bridge was necessary to prevent damage by flash floods. This year's entries were required to be 23 ft long and capable of carrying 2,500 lb.

On Friday afternoon, the teams participated in the display portion of the competition, and all of the bridges were assem-

Geoff Weisenberger is the senior editor of *MSC*. You can reach him at **weisenberger@modernsteel.com**.

The University of Illinois at Urbana-Champaign (top) and University of Louisiana, Lafayette (bottom) teams, during the assembly portion.

The University of California, Berkeley team, overall winners, at the awards banquet.

University of Akron team members race against the clock.

bled for public display and judging. This segment provided a chance for student teams to display and share their innovations, as well as learn how other teams approached the design and fabrication of their bridges.

"I was surprised that even though all teams are using the same set of rules, each team had a unique solution to the problem," said Scott D. Schiff, Ph.D., professor of civil engineering at Clemson and the faculty advisor for the Clemson team and Clemson Chapter of SEA of South Carolina.

On Friday evening, the National Rules Committee (which develops and modifies the competition rules each year) hosted a captains' meeting to provide one last opportunity for teams to get clarifications on the rules related to the assembly or load testing of their bridges. In parallel with the meeting, the other members of the steel bridge teams had the opportunity to showcase their "Fe" knowledge in a quiz bowl sponsored by the National Council of Examiners for Engineering and Surveying. After both, the teams had a little time to relax and enjoy a BBQ dinner and ice cream sundaes.

"Saturday's competition is always a bit nerve-racking for the teams," said Schiff. "They've spent many months preparing for this event and any mistakes by the builders in the 'one-chance' assembly of their bridge during the timed competition, or issues in the design or performance of their bridge, can be very costly."

This year, streaming video cameras were set up so that spectators could watch the competition over the Internet. Over 2,000 people watched and commented on Saturday's competition, and more than 100 representatives from the steel industry or the structural and civil engineering design communities were also in attendance as either national or local sponsors of the competition, volunteer judges to oversee the competition activity or members of the National Rules Committee. Many of these industry representatives have been involved with the competition for years.

"This year was my return back to judging after an enjoyable four-year term on the rules committee," said judge Renee Carter Whittenberger, P.E., a bridge engineer in Akron, Ohio and a former NSSBC team captain herself. "I noticed that my judging experience was much different this year as compared to my previous years judging, having now participated in the writing of the rules. As it turns out, by 10 a.m. I had earned the reputation as the toughest enforcer of the rules on the floor!"

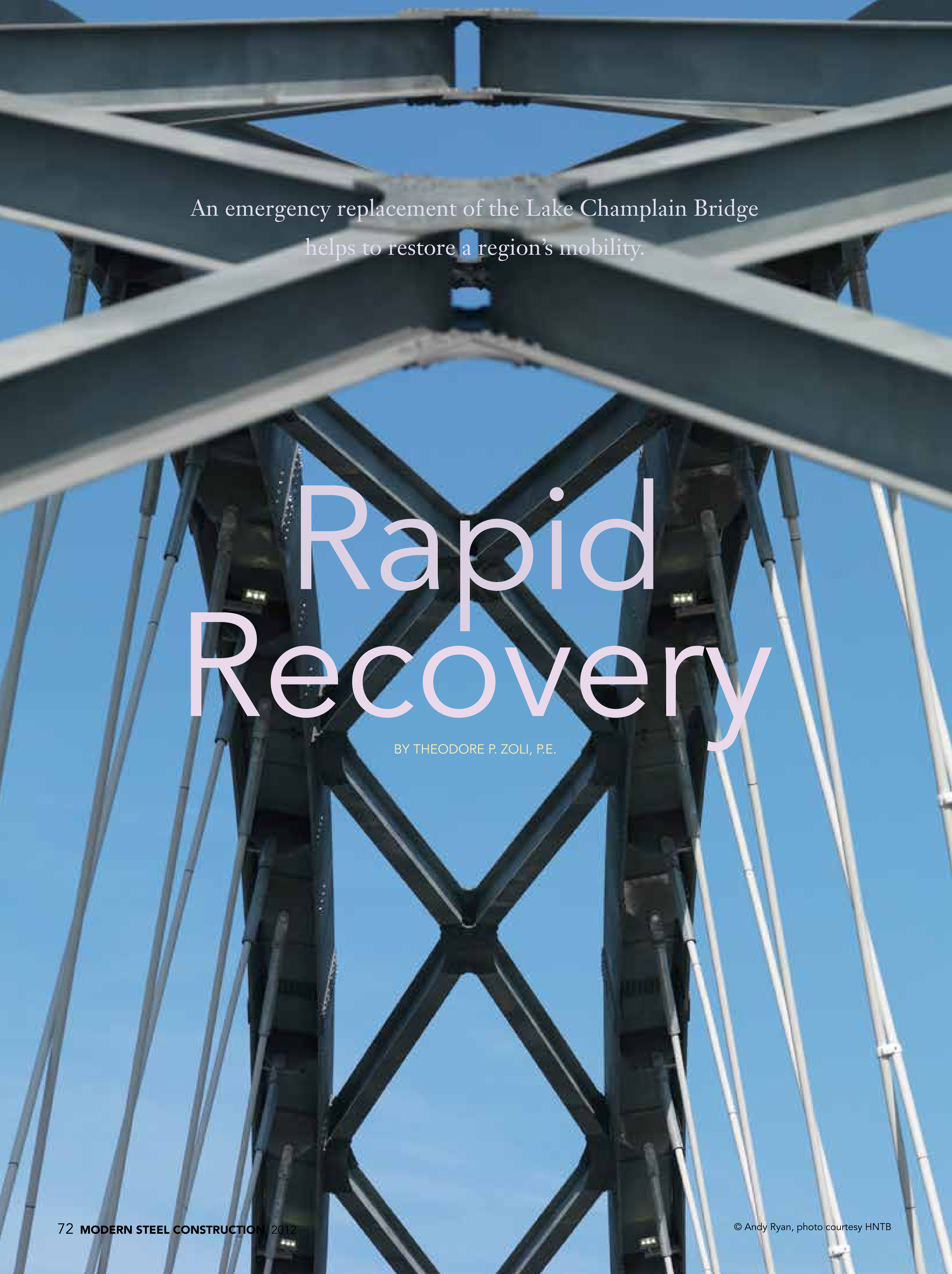
The planning efforts of the Clemson University host committee, in cooperation with the National Rules Committee, resulted in Saturday's competition being completed in record time. By 4:00 p.m., all teams were back at their hotels and getting ready for the NSSBC Banquet and Awards Ceremony.

The banquet provided an opportunity to recognize the sponsors of the event and the staff and volunteers that organized the competition. There were two keynote presentations, one focused on the structural steel design of the Boeing Facility in Charleston, S.C. and the other focused on the use of structural steel in accelerated bridge construction. Following these presentations, the awards for both the individual categories and the overall competition were announced.

"It's exciting to watch the next generation of structural engineers come together and work with such passion and enthusiasm," said Nancy Gavlin, AISC director of education. "This year's bridge posed difficult challenges that the students faced with ingenuity and professionalism."

"All of the competitors brought their best to Clemson, and represented themselves well," said Matthew Cataleta, principal laboratory mechanician for UC Berkeley's CEE department lab and the lab staff advisor for the team. "At the same time that they competed with each other, they also all seemed very open to the sharing of their ideas and proud of the individual efforts that they made to meet the challenges of the competition."

For more information on the NSSBC, visit **www.aisc.org/steelbridge** or **www.nssbc.info**. MSC



An emergency replacement of the Lake Champlain Bridge helps to restore a region's mobility.

Rapid Recovery

BY THEODORE P. ZOLI, P.E.

© Andy Ryan, photo courtesy HNTB


© Trey Cambern Photography, photo courtesy HNTB

▲ The center arch span was assembled on the shore of Lake Champlain and floated by barge two miles to the awaiting approach spans.

MUCH HAS BEEN WRITTEN about the emergency replacement of the Lake Champlain Bridge—from the unprecedented collaboration between the bi-state owners, New York and Vermont, and the Federal Highway Administration to the successful pre-assemble-and-lift scheme.

But little has been said about the critical role steel played in expediting the project. Without steel, the preferred design alternative would have been impossible, the expedited schedule and the budget would have been in jeopardy and the project would not have been able to deliver a critical new lake crossing in record time.

Closure Creates a Rift

The $76 million emergency replacement structure reaches 2,200 ft across a narrow spot in Lake Champlain, reconnecting the towns of Crown Point, N.Y., and Chimney Point, Vt. It was completed slightly more than two years after the former Lake Champlain Bridge was closed suddenly, due to concerns about the integrity of its piers. Declaring the bridge out of service was a stinging blow to residents' quality of life and their symbiotic economies, as there is not another roadway crossing in either direction for several miles.

Before Vermont and New York declared states of emergency and the New York State Department of Transportation (NYSDOT) closed the bridge on October 16, 2009, nearly 3,500 motorists a day relied on the 80-year-old structure as the most efficient route to work, school or even the grocery store.

After determining that strengthening and retrofitting the structure would neither be adequate nor cost-effective, NYSDOT and the Vermont Agency of Transportation (VTrans) announced on November 2009 that they would demolish the historic structure, construct a temporary ferry service and build a replacement bridge.

To expedite replacement of the existing bridge, NYSDOT developed a delivery strategy to complete design on a compressed schedule with the traditional, linear functions of final design, bid packaging, advertisement and permitting performed concurrently. The delivery strategy has been named "dynamic design-bid-build" (D2B2), and was executed at unprecedented speed for a bridge of its size. HNTB Corporation was the design consultant on the project and designed the modified network tied-arch bridge in just 10 weeks, delivering 95% of the plans and specifications in March of 2010. Detailing by Tensor Engineering began in April, and steel fabrication began in early July. The fabricator, High Steel Structures, began shipping steel to the jobsite in December 2010, and contractor Flatiron Construction erected the first girders in January 2011.

◄ The new Lake Champlain Bridge is built from 4,021 tons of steel.

Safer, Sustainable, Signature Steel Span

The new Lake Champlain Bridge (also known as the Crown Point Bridge) is composed of a total of eight spans with one network tied-arch signature span. The total bridge length is 2,200 ft, with seven approach spans, measuring up to 250 ft each, connected by a 402-ft-long, 8-story-tall steel arch span anchored by two 40-ft-deep rigid frame delta-leg girder assemblies. It was constructed with 4,021 tons of Grade 50W and Grade 70 HPS metalized steel.

Theodore P. Zoli, a 2012 *ENR* Newsmaker and a 2009 MacArthur Foundation Fellows winner, is chief bridge engineer in charge of technical aspects of HNTB Corporation's bridge practice. You can contact him at **tzoli@hntb.com**.


© 2011 Bruce Katz, photo courtesy HNTB

Each cable has seven 0.6-in.-diameter strands.

The arch is made from 902 tons of steel.

During the design process, HNTB presented six replacement alternatives during a rigorous six-day public involvement process, which began in December 2009. Of the six, four were steel structures and two were concrete. The decision to adopt a steel versus concrete superstructure had much to do with the project's fast-tracked schedule and the difficult winters typical of Upstate New York and Vermont. Cast-in-place concrete construction represented significant risks for schedule delays, given reduced winter productivity, making concrete alternatives that included balanced cantilever segmental and cable-stay bridge types less attractive alternatives. Both foundations and cast-in-place piers for the new bridge highlighted the difficulties inherent to cold-weather concreting in harsh climates. Extensive tenting and heating were required for multiple piers to maintain schedule, and significant construction activities continued year-round. The potential for lost days due to cold weather associated with a cast-in-place concrete superstructure would have negatively impacted the project schedule. Using steel and minimizing the amount of cast-in-place concrete work turned out to be the right decision, given that the significant approach superstructure construction activities took place throughout the winter months.

Not only that, but steel also had the public's support. After an unprecedented level of public input on the design alternatives, residents overwhelmingly voted in favor of the modified network tied arch. The new bridge, which had a form that was quite distinct from Charles Spofford's (the designer of the original bridge) continuous truss, still had an echo of the old bridge's form. The use of steel for both the old bridge and the new gives a sense of how differently the materials are used in new designs; trusses that in the past used thin plates, lattice work and gussets had given way to robust girders, delta frames and arch ribs.

Staying Informed

An accelerated design schedule is meaningless if it results in a bridge that is more difficult to fabricate, transport and build. Therefore, the construction strategy influenced the design. The basic design premise for fast-track construction is that the approaches and main span need to be fabricated and erected more or less simultaneously. This meant float-in and heavy lift construction for the arch was the only choice, and the approach delta frames would serve as a base for the crane for heavy lift operations.

On August 26, 2011, the center arch span, assembled on the shore of Lake Champlain, was floated by barge two miles to the

▲ The center arch span was lifted 75 ft into place.

➤ Night work on the bridge.

Photos this page: © Trey Cambern Photography, photo courtesy HNTB

awaiting approach spans and lifted 75 ft into place. Arch stability was a crucial part of the erection sequence, not just during float-in and lift operations but also during concrete panel installation, when the arch saw more deformation than at any other time and when its stability was most compromised. Flatiron worked with erection engineer, Erdman Anthony, to ensure a safe and fast erection before the remnants of Hurricane Irene struck the area less than two days later.

Given the complexity of the steel structure, the tight tolerances and the short schedule, there were concerns about fit-up during construction. However, within a few days after arch assembly, Flatiron requested daily steel shipments to keep up with erection activities. In all, construction and the lift went remarkably smoothly, a testament to High Steel's precision in fabrication and shop assembly.

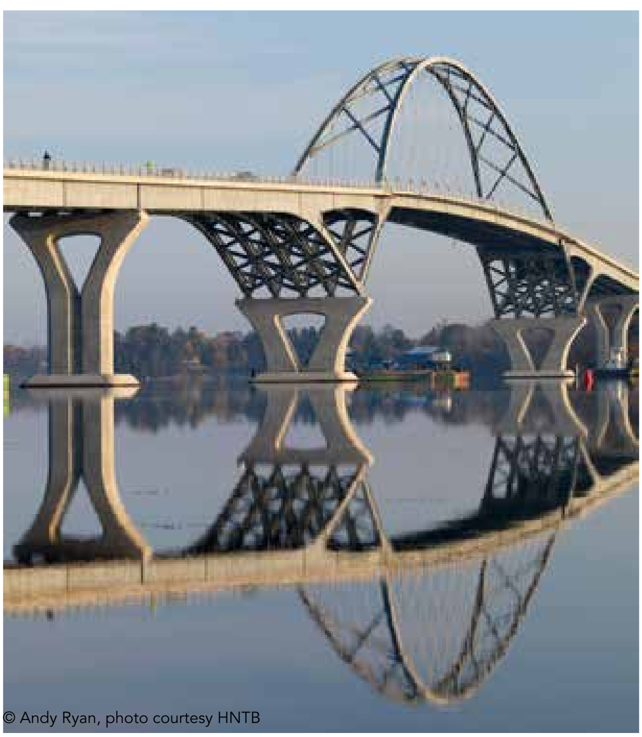
An Evolving Arch

An evolution of a conventional tied arch bridge, the bridge uses inclined hangers that cross at least twice instead of vertical cables and hangers (the cable system is comprised of 44 cables per arch plane, and each cable has seven 0.6-in.-diameter strands). This crisscross pattern helps distribute the weight of the main span throughout the structure, making the overall system much more redundant; one or multiple cables can be damaged or lost without impacting the safety of the system. Additionally, the tie girder is designed as a built-up section and is therefore internally redundant. By making the tie girder composite with the longitudinally post-tensioned precast concrete deck, an additional level of redundancy is provided.

The use of multi-girder delta frames offers a unique and highly redundant way in which to support the arch. The arch bearings fall in between the outside two girder lines. Additionally, heavy lateral bracing connects all five girder lines, and a continuous transverse box beam connects the top of the delta frames. This arrangement provides for redundancy in that the system can tolerate the loss of any one of the delta frames through redistribution. The post-tensioned deck slabs also were designed to span the loss of a floorbeam at the limit state, such that all fracture-critical elements are eliminated.

To protect the majority of the bridge's superstructure from de-icing salt spray, HNTB designed generous deck cantilevers

© Trey Cambern Photography, photo courtesy HNTB



© Andy Ryan, photo courtesy HNTB

▲ Crowds watching the arch lift.

◀ The completed bridge, once again linking both sides of the lake.

in the approach sections, adding extra thickness to the arch ribs in the above-deck superstructure and shop-applying a durable corrosion-protection system comprised of an 85% zinc and 15% aluminum thermal spray coating. These preventive measures are expected to extend the life of the bridge and reduce long-term maintenance costs.

It also is critical that the structural steel be readily accessible both for inspection and future maintenance. The tie girder is a bolted box with inspection access from the inside, and the arch and all approach girders are I-sections. The height of the arch rib above the deck was limited to allow for inspection access via man-lift.

The new Lake Champlain Bridge opened to traffic last November, and once again residents are able to drive across the lake—now via a safer, modern bridge with greater redundancy and a longer life. MSC

Owners
New York State Department of Transportation and Vermont Agency of Transportation

Structural Engineer
HNTB Corporation, Albany and New York City

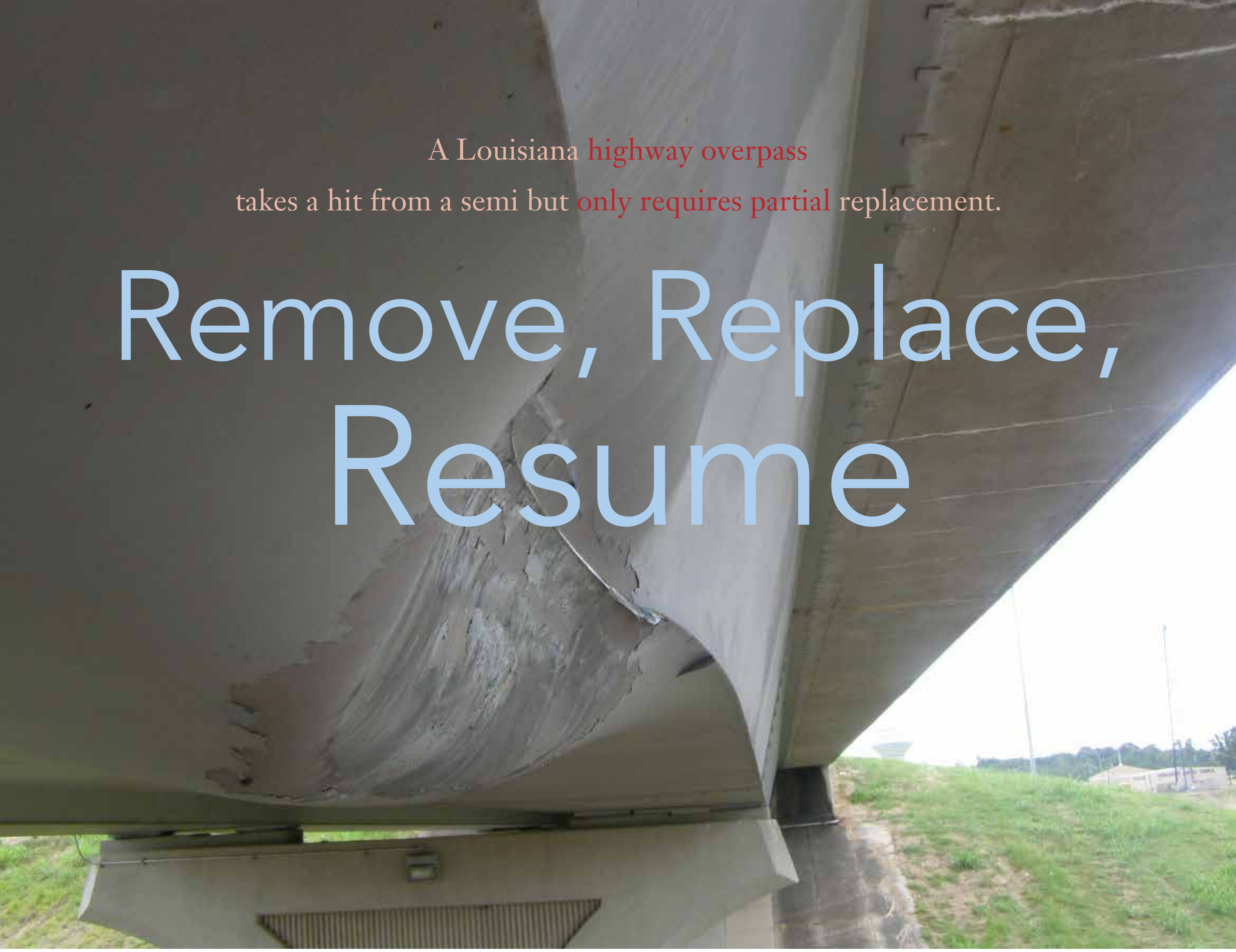
Erection Engineer
Erdman Anthony, Mechanicsburg, Pa.

Steel Team

Steel Fabricator
High Steel Structures, Inc., Lancaster, Pa.
(AISC Member/NSBA Member/AISC Certified Fabricator)

Steel Detailer
Tensor Engineering, Indian Harbour Beach, Fla.
(AISC Member/NSBA Member) – bridge approaches
Candraft Detailing Inc., New Westminster, B.C.
(AISC Member) – bridge arch

General Contractor
Flatiron Construction Corporation, Firestone, Colo.



A Louisiana highway overpass takes a hit from a semi but only requires partial replacement.

Remove, Replace, Resume

▲ The box girder, post-collision.

BRIDGES ARE DESIGNED for wear and tear over their lifespans. But sometimes a whole lot of wear and tear can happen all at once.

On July 14, 2008, an over-height vehicle travelling east on the Bert Kouns Industrial Loop Expressway in Shreveport, La., struck the west box girder of the southbound I-49 overpass. The vehicle was a tractor-trailer carrying a wind tower segment on its side.

The damaged overpass structure was a three-span continuous unit with span lengths of 90 ft, 147 ft and 90 ft. The 147-ft span (middle span) crosses over the four lanes of the Bert Kouns Expressway and consists of two steel box girders topped with the concrete deck.

The Louisiana Department of Transportation and Development's (DOTD) Shreveport District immediately assessed the damage and restricted overpass traffic to one lane, directly over the undamaged box girder.

Two days after the collision, engineers from the DOTD's Bridge Design Section in Baton Rouge and the Shreveport District conducted a thorough damage inspection. The impact point was found to be near the center of the 147-ft middle span—one of the highest stress points on the structure. The damaged span contained an 86-ft spliced segment that was centered within the span, placing the splice plates near the edges of the four-lane Bert Kouns Expressway and the impact point nearly equidistant from each splice. This was fortunate, as it meant that damage could potentially be contained within the spliced segment, which could be removed and replaced.

The impact point exhibited permanent deformation of the web and bottom flange. The deformation involved approximately 50% of the web and 50% of the bottom flange and was basically a very large dent centered on the web-to-flange weld. A dye penetrant test was performed and found no cracking along the web-to-flange weld within the impact zone.

Internal inspection of the box girder revealed buckled cross-frame members and fractured connection plates (which also serve as web stiffeners) throughout the full length of the 86-ft spliced segment, and one cross-frame connection plate crack was found just outside of the spliced segment. Luckily, the crack was small, non-critical and could have been from normal operational stresses rather than the impact, as sometimes seen on other bridges where connection plates are welded to the flange.

Review of the site indicated that the only anticipated environmental impacts from repair construction would be interruptions to vehicle traffic. Southbound I-49 traffic would likely experience short durations of single-lane closures and

photos courtesy of LA DODT

◄ Damage to the cross-frame connection plate.

► The new section is put in place via a pair of cranes.

▲ The damaged section of the bridge, after being cut and before being removed.

▼ The damaged section is removed via self-propelled modular transporters.

complete closures. The complete closures could possibly be relieved by diverting traffic through the off and on ramps, since this was a typical "diamond" interchange. The Bert Kouns Expressway would also experience short durations of closures.

One Lane or Two?

The biggest question at this point was whether or not the overpass could go back to carrying two lanes of traffic while repair plans were being developed.

The overpass carries a 40-ft clear roadway width. As often seen on four-lane roadways, the right shoulder was wider than the left. The right shoulder was also nearest the damaged girder, which meant the two striped traffic lanes were closer to the undamaged girder. The design team determined that by closing the right shoulder, the damaged girder would experience an acceptable amount of live load with respect to its reduced safe service level capacity. Fatigue stresses were determined not to be an issue, thanks to the relatively short duration before repairs would be made.

On August 14, exactly one month after the incident, the Bridge Design Section (performing the evaluation) notified the Shreveport District office that the overpass could be opened up to two lanes of traffic with the right shoulder closed. To assure that strength was not an issue, no permit vehicles or vehicles above the legal weight limit (41.7 tons) were allowed on the structure. Additionally, all observed cracks and cross frame deflections were measured, marked and monitored for changes during repair plan development. Any changes observed in existing damage, or appearance of new damage, would result in evaluation and possibly reducing the overpass to one lane of traffic.

The goal of repairing damage from such an incident is to return the structure to its condition just prior to the incident, and to do so without adding any additional maintenance or inspection requirements for the remaining bridge life (the structure was built in 1991, making it only 17 years old at the time of the incident, with most of its intended service life remaining). The options of patching, spot repair or fortifying the girder would prevent future collapse, but would leave the structure with special inspection requirements and possibly make it


LA DODT

more vulnerable to a future collision. Seeking a more long-term solution, DOTD decided the best option would be to fabricate a new girder segment, deliver it to the site, remove the spliced girder segment with deck and concrete railing and reconstruct the segment.

Analysis revealed that existing dead-load shears and moments in the splices should allow the splices to be unbolted, with the splice loads released onto the remaining structure without producing excessive stresses or deflections. Consideration was given to both non-composite and composite moments at splice locations in order to determine the total amount of moment that would be transferred to the splice prior to girder removal.

The analysis also indicated that shoring would not be required for the replacement project. Under the chosen repair solution, slight stress increases would be locked into the undamaged box girder due to sequence of loading, but analysis indicated these values would be within limits. A separate contract was initiated during plan development to install strain gauges on the structure to both monitor stresses during construction, and to verify stress effects from the repair.

The repair plans provided a camber diagram for the new box girder segment and highlighted that the camber diagram shown in the original bridge plans was not to be used, since different loadings would be placed on the new girder segment. The plans required the general contractor, Gibson and Associates, to field-verify all dimensions and determine splice rotations prior to all fabrication. Splice rotations would not only be affected by the possible elected use of shoring and other removal means and methods, but also by the actual loads in the splices and stiffness of the structure, which could only be approximated by the analysis performed during plan development. At the splices, a gap larger than the existing gap was allowed to facilitate differences between the calculated and actual rotations that would likely occur. Therefore, the splice plates could be fabricated larger than existing as well, in order to obtain the required bolt edge distances. The repair plans required shop drilling of all splice plate holes, but allowed either shop or field drilling of bolt holes in the new girder segment.

Cut it Out

The repair sequence began with removing a 4-ft-wide strip of deck concrete longitudinally along the center of the roadway in order to provide enough splice development length in the transverse (main) deck reinforcement. The removal strip turns transverse to the roadway just beyond the girder splice points to facilitate installing new girder flange splice plates, provide enough development for the longitudinal deck steel splices and to have some flexibility in the remaining box girder ends to allow splicing of the new girder segment.

The deck strip removal was initiated with a 1-in.-deep saw cut, for control purposes. Large-radius corners were used where the strip turns transverse, in order to minimize corner stresses in the deck. The concrete was then removed by hydro-demolition in order to preserve the integrity of all deck reinforcement. Once the concrete strip was removed and the reinforcing steel was cut, the damaged box girder, along with its composite portion of deck and barrier railing, was supported, un-spliced and removed.

Upon installing the new box girder segment, one lane of traffic was allowed over the undamaged girder. Previously placed temporary concrete barriers along the roadway centerline kept vehicles from entering the open hole in the deck, which measured half the bridge width and 91 ft long, with only the steel box girder beneath. Placing the deck and barrier concrete required a full roadway closure. After curing, the overpass was once again opened to full traffic. (Traffic on the Bert Kouns Expressway below was also closed during the removal and replacement of the box girder, installation of formwork and a few other brief operations.)

The new girder (approximately 23 tons, the same weight as the original) fit with very little difficulty. Self-propelled modular transporters (SPMTs) were used to remove the damaged girder, deck and barrier segment, and two cranes were used to erect the new box girder. This required the use of slings, straps, blocking, flange edge softeners and clamps to lift and hold the girder in position while the splices were connected.

Construction was completed October 2009, for a total construction time of eight months. However, the total duration of complete lane closure on the overpass was only five nights and one day, in which the Bert Kouns Expressway was closed and I-49 was diverted through the interchange. MSC

Owner/Designer
LA DOTD (Louisiana Department of Transportation Development)

Steel Team

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

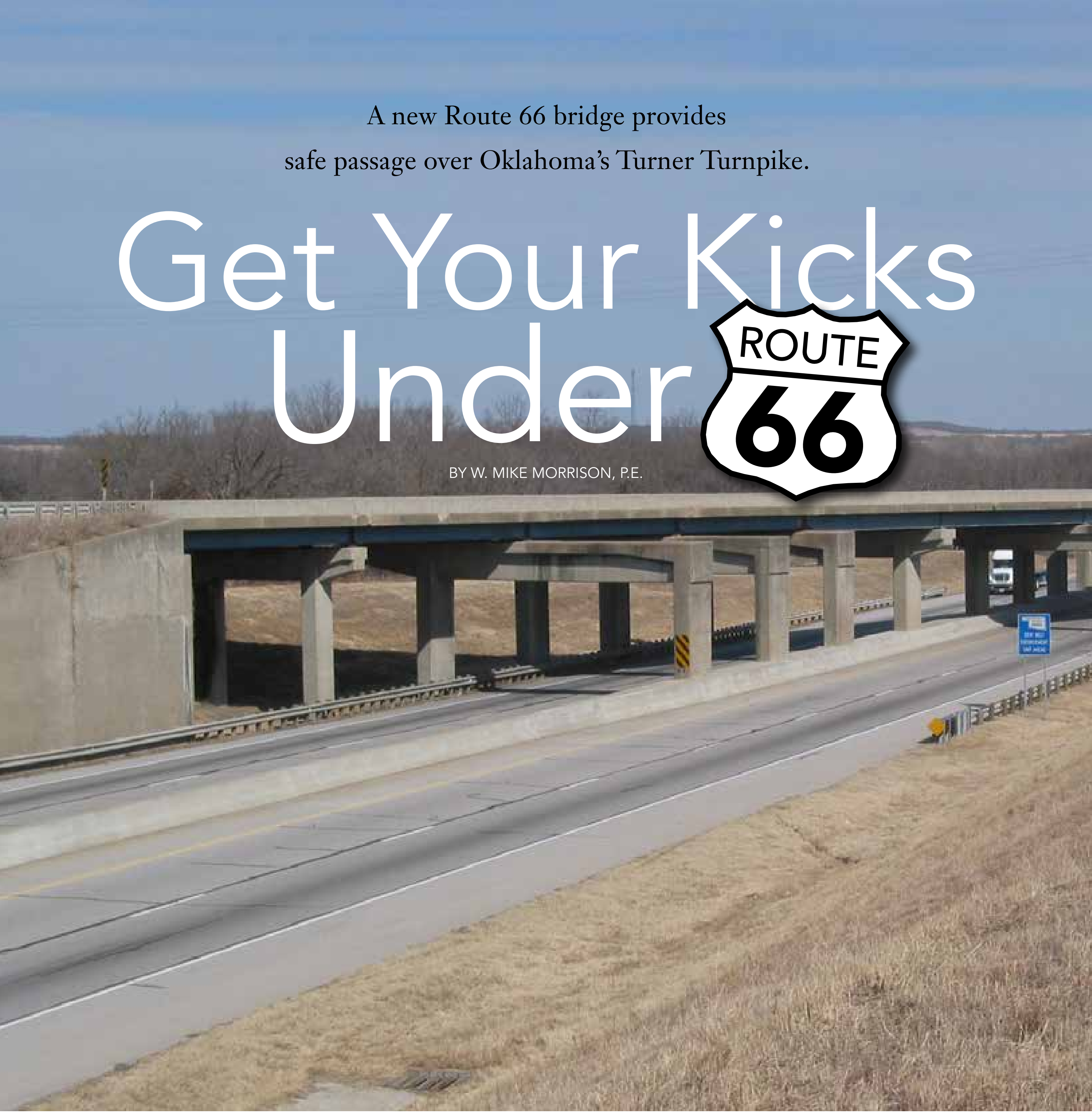
Detailer
ABS Structural Corp., Melbourne, Fla., (AISC Member)

General Contractor
Gibson and Associates, Inc., Balch Springs, Texas

A new Route 66 bridge provides safe passage over Oklahoma's Turner Turnpike.

Get Your Kicks Under ROUTE 66

BY W. MIKE MORRISON, P.E.



THE TURNER TURNPIKE has provided a link between Oklahoma's two largest cities for nearly six decades.

Opened to traffic in 1953 and assigned the Interstate 44 designation between Oklahoma City and Tulsa, the four-lane, 86-mile stretch was constructed in roughly 30 months at a cost of $38 million.

With traffic volumes increasing every decade since the corridor's opening, the Oklahoma Turnpike Authority (OTA) began planning for a six-lane widening of the Turnpike in the early 1990s. Several ideas were studied—including the environmental, utility and right-of-way impacts—and presented in a 1995 report suggesting an offset alignment, parallel to and north of the existing alignment, with a wider median and a six-lane typical section. Several major bottlenecks along the Turnpike were also identified, including the Route 66 Bridge (Bridge 68.2) that crosses the Turnpike in Creek County, known locally as the "Grasshopper Bridge" due to its staggered piers.

When it opened to traffic, the Turner Turnpike essentially replaced historic Route 66, crossing the original highway at several locations. At this location, Route 66 crosses the Turnpike on a very sharp 16° angle, which required a fairly long bridge, 423 ft, using somewhat unconventional straddle-beam

➤ The original bridge crossed the Turner Turnpike on a 16° angle. The staggered pier columns prompted its nickname, the "Grasshopper Bridge."

➤ The new bridge crosses the Turnpike on a 30° angle, supported by four steel plate girder spans.

piers to clear the Turnpike below. The original bridge was comprised of 11 steel I-beam spans, ranging from 35 ft to 54 ft in length, resting on two vertical abutments and ten piers, eight of which straddled the Turnpike in four locations on each side of the highway.

With overhead pier caps and columns along both shoulders and down the median, driving through the original bridge resembled driving through a tunnel, with only approximately 6 ft and 15 ft of lateral and vertical clearances, respectively. The limited overhead clearance resulted in several of the straddle beam pier caps being struck by tall vehicles, causing major concrete damage and exposing the main reinforcing steel. The bridge geometrics on Route 66 were also limited, with two lanes of traffic on a 28-ft-wide roadway. The existing bridge was unsafe for both throughways and because of the collision damage, it was labeled structurally and geometrically deficient, with a sufficiency rating of 42.4 (out of 100). The Grasshopper Bridge would have to be replaced.

The OTA put the widening plan to rest for several years before reconsidering the idea in the early 2000s. The first portion of the project began near Tulsa, with the replacement of one of the larger bridges in that area. Following that project, with the Grasshopper Bridge being the next major bottleneck to the west, the OTA hired W2M Consulting in 2006 to perform a design study and prepare the final design for its replacement.

The primary objective of the OTA was to design a grade separation that would meet current design standards and significantly improve the lateral and vertical clearances along the Turnpike, while also accommodating for the future widening. One of the first courses of action was to determine whether the existing bridge had any historical significance due to its odd configuration and for its location on Route 66. Fortunately, the bridge was not listed on the National Register of Historic Places, nor was it registered or eligible in the Oklahoma Department of Transpor-

W. Mike Morrison is president of W2M Consulting, LLC. You can reach him at **w2mconsulting@coxinet.net**.

Photos courtesy of W2M Consulting

Roadway view along the new bridge deck. Note the reverse superelevation transition near the middle of the bridge.

View below span 3, showing the five girder lines with inverted K braces and the drainage collection system.

tation (ODOT) publication *Spans of Time*, so it could be removed without raising historical concerns.

Four options were developed for the realignment of Route 66 at this location. Full lateral clear zones, with safety slopes, were incorporated along the Turnpike, using a six-lane configuration with a minimum vertical clearance of 16 ft, 9 in. over the Turnpike.

Alternates 1 and 2, based upon the suggestion in the 1995 report, offset the new bridge to the southwest of the existing bridge on a more appropriate skew angle, the only difference between the two options being the degree of curvature (1°30' and 2°) for the horizontal curves on Route 66 approaching the bridge. Both options included a 60° skewed bridge with spans of 104 ft, 162 ft, 162 ft and 104 ft.

Since Route 66 was on a straight alignment for nearly two miles in each direction from the bridge, the design team also felt obligated to provide an option for reconstructing the bridge on the existing alignment. However, this option would have required closing Route 66 for construction since there was no feasible method for staging the construction efforts around the existing bridge. Because of the lateral constraints along the Turnpike, the required bridge length for this option was much longer, 618 ft, with essentially the same substructure configuration as the existing bridge (straddle-beam piers). This option was listed as Alternate 4, using two three-span continuous units of 94 ft, 121 ft and 94. Alternate 3 incorporated the same substructure configuration as Alternate 4, but on a 100-ft offset and parallel alignment to the south of the existing highway that allowed construction without closing the existing bridge. Alternate 3 also used two three-span continuous segments, but with span lengths of 107 ft, 101 ft and 101 ft. Due to conflicts with the existing foundations, though, the span arrangements for Alternate 3 were not as practical for design economies as the layout for Alternate 4. Nevertheless, it was the only viable layout for the offset and parallel option.

Through several meetings with the OTA and ODOT, Alternates 3 and 4 were discarded in favor of Alternate 2: the southwest offset alignment on a 30° crossing with longer radius horizontal curves. The major factor in not selecting Alternates 3 or 4 was the straddle beam pier caps, as they were deemed "fracture critical" components, as opposed to the more conventional piers that would be placed parallel to the Turnpike in Alternate 2.

The allowable superstructure depth and the grades on both the Turnpike and Route 66 played a large role in determining the girder types for the different bridge configurations. Both facilities were already on fairly mild downward grades with very good site distances. However, the Turnpike grade could not be changed, leaving all the grade modifications to the profile on Route 66. With the already low clearance to the Turnpike, the girders had to be as shallow as possible to lessen the grade impact on Route 66. For the span lengths involved in all four options, steel was the only viable material for minimizing the superstructure depth. A two-span bridge was considered, but it required

Channel and plateend diaphragms at an expansion pier.

considerably deeper steel members or post-tensioned concrete box girders up to 12 ft, 6 in. deep that simply would not work geometrically. Shorter spans for using prestressed concrete beams were also considered, but those options were discounted due to the skew of the crossing and the substructure conflicts along the Turnpike. A four-span, steel bridge, again on a 30° crossing, was clearly the best arrangement.

After being asked to relax the clear zone requirements to reduce the overall bridge length, the final configuration was established at four spans of 112 ft, 136 ft, 136 ft and 112 ft, using a 40-ft clear roadway on the bridge with F-shaped concrete parapets. The outer spans were designed as simply supported while the two interior spans were made continuous across the middle pier. And although the bridge is straight, a reverse super-elevation transition was required directly over pier 2 between the reverse horizontal curves on each end of the bridge.

The steel design was based on the 4th Edition LRFD *Bridge Design Specifications* using the HL-93 and the ODOT policy "Oklahoma Overload Truck." Five steel plate girders on 9-ft centers with an 8-in. concrete slab comprise the superstructure on a -0.6% grade along the length of the bridge. Grade 50W steel was provided with constant depth 54-in. webs and 18-in. flanges of varying thicknesses. Inverted K braces were provided perpendicular to the girders throughout the bridge, and channel and plate diaphragms were provided at the abutments and expansion piers 1 and 3, along the skew. In addition, bolted field splices were designed and detailed at the dead load contra-flexure points on either side of pier 2 in the two-span continuous unit.

Deck drainage was also a critical design issue as runoff water was not allowed to fall to the Turnpike below. With a reverse super-elevation transition over the middle pier and the bridge on a constant down grade, runoff water had to be collected and removed from the bridge. In addition, runoff water had to be collected along each gutter line because had it been allowed to cross the roadway over pier 2 (at the super transition point), more than an inch of water would have been crossing the highway at the design flow rate. The overall project included a 496-ft-long, four-span bridge, 3,925 ft of realignment on Route 66, 3,324 ft of county road realignment and the extension of a double cell bridge box at the eastern end of the project. It was completed this spring at a cost of $8.9 million and involved 375 tons of structural steel. MSC

Author's note: This article is dedicated to the memory of my wife's grandfather, John W. Stakle, project engineer with De Leuw, Cather and Company (general consultant to the OTA) during the original design and construction of the Turner Turnpike.

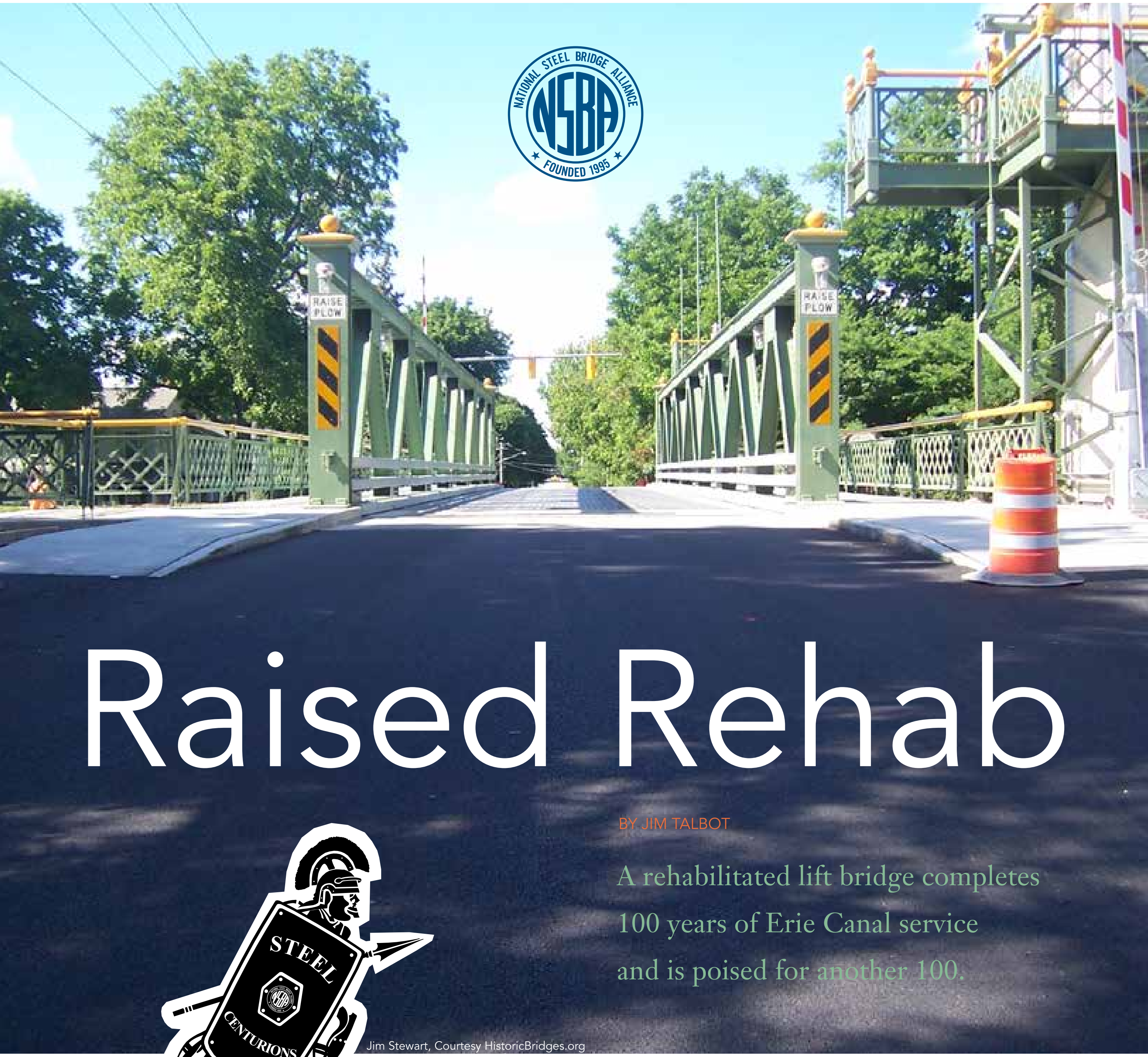
Owner
Oklahoma Turnpike Authority and Oklahoma Dept. of Transportation

Structural Engineer
W2M Consulting, LLC, Oklahoma City

Steel Team

Fabricator and Detailer
DeLong's, Inc., Jefferson City, Mo. (AISC Member/NSBA Member/AISC Certified Fabricator)

General Contractor
Becco Contractors, Inc., Tulsa



Jim Stewart, Courtesy HistoricBridges.org

Raised Rehab

BY JIM TALBOT

A rehabilitated lift bridge completes 100 years of Erie Canal service and is poised for another 100.

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 ERIE CANAL, completed in 1825, links Lake Erie in western New York to the Hudson River in the east. It originally included 18 aqueducts and 83 locks, descending 568 ft from west to east. Among the many factors that make the Erie Canal historically significant are the bridges spanning its nearly two centuries of life. The canal, particularly the western section, has one of the highest densities of historic bridges of any waterway in the country.

From 1905 to 1918 the state upgraded and widened the canal, making it suitable for barges carrying up to 3,000 tons of cargo. The resulting waterway, completed in 1918, is 12 ft to 14 ft deep, 120 ft to 200 ft wide and 363 miles long, reaching from Albany to Buffalo. It includes 57 locks with lifts of 6 ft to 40 ft. The steel replacement bridges for the widened canal have proved to be very durable. Moreover, the New York Department

The Washington Street Lift Bridge turned 100 this year.

of Transportation (NYDOT) and other agencies have committed to their preservation, keeping them in excellent condition. One such bridge, the Washington Street Lift Bridge (also known as the Adams Basin Lift Bridge) became a Centurion this year. It's located in the hamlet of Adams Basin in the town of Ogden, about 12 miles west of Rochester.

Structurally, the design of the Washington Street Bridge is a rivet-connected Warren pony truss. The bridge has a total length of 144.7 ft and a deck width of 18.4 ft. The Warren truss consists of diagonal members only—no verticals. The term "pony" means that the truss has no bracing between the top chords. The word "Cambria" stamped on the bridge indicates that the steel came from the Cambria Steel Works in Johnstown, Pa. (the same plant that supplied the Greenspot Road Centurion bridge in the June issue).

The lift mechanism used is relatively unusual. Vertical end posts extend below the deck and into the ground. When operated, the end posts rise out of the ground. Stairways from the sidewalks at each end of the bridge allow pedestrians to continue to cross the bridge even when it's in the raised position. Raised, the bridge provides about 15 ft clearance over the water. Interestingly, the operator of this bridge also works the Union Street Lift Bridge about two miles down the canal in Spencerport; the operator drives to the Washington Street bridge when notified of a boat needing to pass.

A $7.3 million project to rehabilitate the Washington Street lift bridge and one other canal bridge began in November 2005. While the work was underway, crews parked and shored it in the raised position to permit boat traffic on the canal. The work replaced deteriorated structural steel of the truss portion and included a new deck system. Additionally, workers removed and replaced concrete elements of the substructure and refurbished the control tower. NYDOT opened the bridge to two-way traffic—plus one of the sidewalks—on December 2006 with no height or weight restrictions.

Additional work on the bridge continued into the summer of 2007. Crews installed new lifting machinery and upgraded the electrical system. They also finished painting, pouring sidewalks and paving the approaches. Businesses and residents in the community greatly appreciated the reopening of the bridge, which helps to ease the traffic flow in the area. MSC

Railing for one of the pedestrian walkways. Thanks to stairways, pedestrians can cross the bridge even in its raised position.

Mill marking for the original steel.

Jim Talbot is a freelance technical writer living in Ambler, Pa.

A Kentucky bridge makes a quick comeback after a ship takes out one of its spans.

Down but not Out

BY TERRENCE TIBERIO AND JASON STITH

Tom Roberts, Hall Construction

▲ The replacement section in place, less than four months after the collapse of the original section.

THE EGGNER FERRY BRIDGE took a knockout punch on January 26.

The MV Delta Mariner, an 8,200-ton cargo ship, struck and collapsed a 322-ft span of the 3,495-ft-long bridge, which carries U.S. Highway 68/KY 80 over Kentucky Lake in the western part of Kentucky. Fortunately no injuries or fatalities resulted from the collapse. However, the subsequent bridge closing cut off a vital link to the area and the western gateway to the Land Between the Lakes National Recreation Area. The detour around the bridge was almost 50 miles.

Immediately after the span collapse, Kentucky Transportation Cabinet (KYTC) investigated a number of options for replacing the span as quickly as possible. Coincidentally, at the time of the collapse, the final design of a replacement to the Eggner Ferry Bridge was already significantly under way. KYTC chose to look at short-term replacement strategies rather than alter the course of the proposed replacement crossing.

An engineering study was performed, giving consideration to multi-span concrete, steel or prefabricated superstructures using light piers in the lake, as well as single-span options without any additional piers. Concerns with putting piers in a potential barge navigation area, as well as preliminary design cost and construction schedule estimates, drove KYTC to choose a single-span steel parallel chord truss to be constructed on the existing piers. This solution would provide vertical clearance equal to or greater than the existing span. It also offered the best potential for KYTC's goal of having the bridge open to traffic on May 27, the day before Memorial Day. In fact, Hall Contracting of Kentucky, Inc., the general contractor, would face liquidated damages of $50,000 per day if it didn't finish the project on time.

Back in a Flash

Less than four months went by between the original span's demise and the new one opening to traffic.

January 26, 2012: The Delta Mariner strikes Eggner Ferry Bridge, collapsing a 322-ft span

February 27: Michael Baker Jr., Inc., (EOR) completes preliminary plans for a single-span steel truss

March 2: KYTC solicits RFQ, specifies open-to-traffic deadline of May 27

March 7: Bids open, Hall Construction awarded contract

March 9: Mill order placed for April rolling

March 14-April 3: Shop drawings completed and approved by Tensor Engineering

April 2: Gusset plate material arrives at United Steel's plant

April 16: Rolled beams arrive at Padgett's fabrication plant

April 24: Truss members begin to arrive at assembly site

May 6: Final truss members arrive at assembly site

May 8: Truss assembly completed

May 14: Truss and cranes loaded onto barges and floated to bridge site

May 15: Truss is set in place and secured on existing piers

May 20: Deck pour completed in one day

May 25: Bridge opens to traffic, two days before deadline

▲ The new section, shown here being lifted into place, weighs approximately 300 tons.

▲ The truss was assembled in less than four weeks on land adjacent to Kentucky Lake.

Terrence Tiberio (ttiberio@mbakercorp.com) is a senior technical manager in the Pittsburgh office of Michael Baker Jr., Inc., and **Jason Stith** (jason.stith@mbakercorp.com) is a civil engineer in Baker's Louisville office.

▲ The truss is assembled on the lakeshore...

▲ ...floated to the site...

Saving Time

Luckily, there were several opportunities for time savings, from design to steel procurement and fabrication. For example, the preliminary design used three-plate welded H-sections for the truss members. However, the project's structural engineer, Michael Baker Jr., realized that using all rolled sections for the truss members along with the wide-flange sections (floor beams and stringers) already designed in the integral floor system, would significantly cut fabrication time; going this route effectively eliminated all shop welding. The truss was redesigned using HP16 members with fill plates. All gusset plates were ¾ in. thick, and no welding was necessary except for field studs on the stringers for the composite concrete deck.

The truss assembly also evolved from the initial design. While preliminary engineering showed the design efficiency of a parallel chord truss without verticals, the use of simplified and repetitive connections details, as well as common member sizes, trumped weight savings for the critical-path construction schedule. The team used MIDAS Civil, a 3D finite element analysis program, to model the truss and the integral floor system and composite concrete deck. Members were designed with in-house code checking spreadsheets and the final truss design was independently checked using the AASHTOWare Virtis software. HP16×183 sections were used for the top chord and end diagonals, HP16×121 sections were used for the bottom chord and HP16×88 sections were used for the remaining diagonals. The top bracing and struts all consisted of W12×40 sections, and the integral floor system was made up of W18×86 stringers and W24×103 floor beams. Therefore only six different rolled sections were used, which helped get the mill order accepted for an early April rolling. This, along with close coordination with the steel detailer (Tensor Engineering), allowed the shop drawings to be completed, reviewed and stamped in less than three weeks.

The tops of the W18 stringers were set below the bottom of the W24 floor beam flange, thus eliminating the need for coping, which also saved fabrication time. In addition, not one of the 13,000 bolt holes used to assemble the truss required reaming on-site, and fabrication was completed in less than three weeks.

Encore

The Eggner Ferry Bridge replacement was actually the second cooperative effort between Michael Baker, Jr. and Hall Construction involving accelerated replacement or repair of a major structure. The first one, which took place just months before the Eggner Ferry Bridge was struck, was an emergency repair of the Sherman Minton Bridge, which was closed on September 9, 2011, due to detection of defects in the non-redundant tie girder of both main span tied arches. The Sherman Minton is a major crossing carrying Interstate 64 over the Ohio River between Louisville and New Albany, Ind., and consists of two double-deck steel tied arch structures, each approximately 800 ft long. Repairs involved the use of more than 1,200 tons of HPS70 steel plate and 287,000 high-strength bolts. That replacement project also opened ahead of schedule and was completed in 17 weeks.

Lakeside Assembly

Thanks to the MIDAS 3D model and using lift-off points proposed by Hall, the team determined that the entire steel truss (weighing about 300 tons) could be lifted without member overstress, and Hall elected to assemble the entire truss on land adjacent to the lake, approximately 29 miles from the bridge site. The truss was assembled in less than four weeks, as gusset plates and rolled members arrived at the assembly area, and was ready to be loaded onto a barge by May 8. The barge,

...lifted into place...

...and ready for action!

along with a deck barge for each of the two barge cranes needed to lift the truss onto the existing piers, arrived at the site on May 14. Deck overhang forms were installed on the barge to expedite construction, and the truss was lifted and secured in place on existing piers on May 15. Following the setting of the truss, the stay-in-place forms and studs were installed, and the concrete deck pour (with curing accelerator) was completed by May 20. The guardrail was then installed and the bridge open to traffic on Friday, May 25, two days ahead of an already aggressive schedule. MSC

Owner
Kentucky Transportation Cabinet

Structural Engineer
Michael Baker Jr., Inc., Louisville

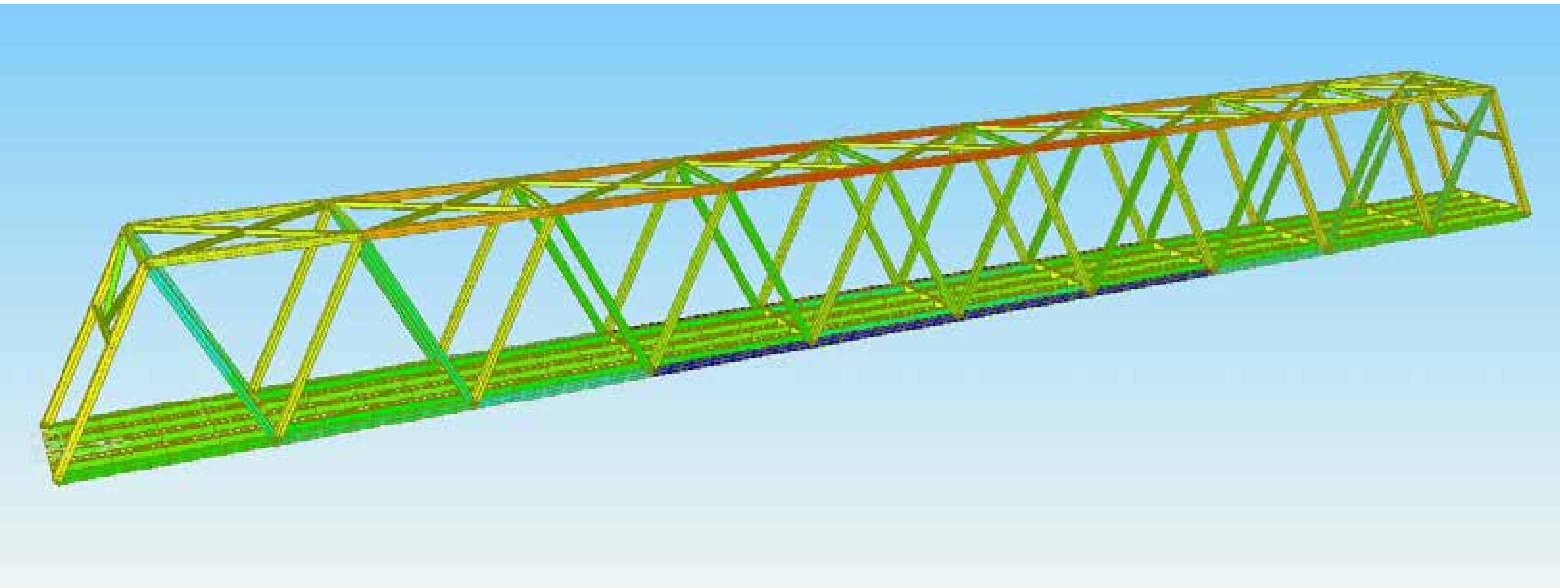
General Contractor
Hall Contracting of Kentucky, Inc., Lousville

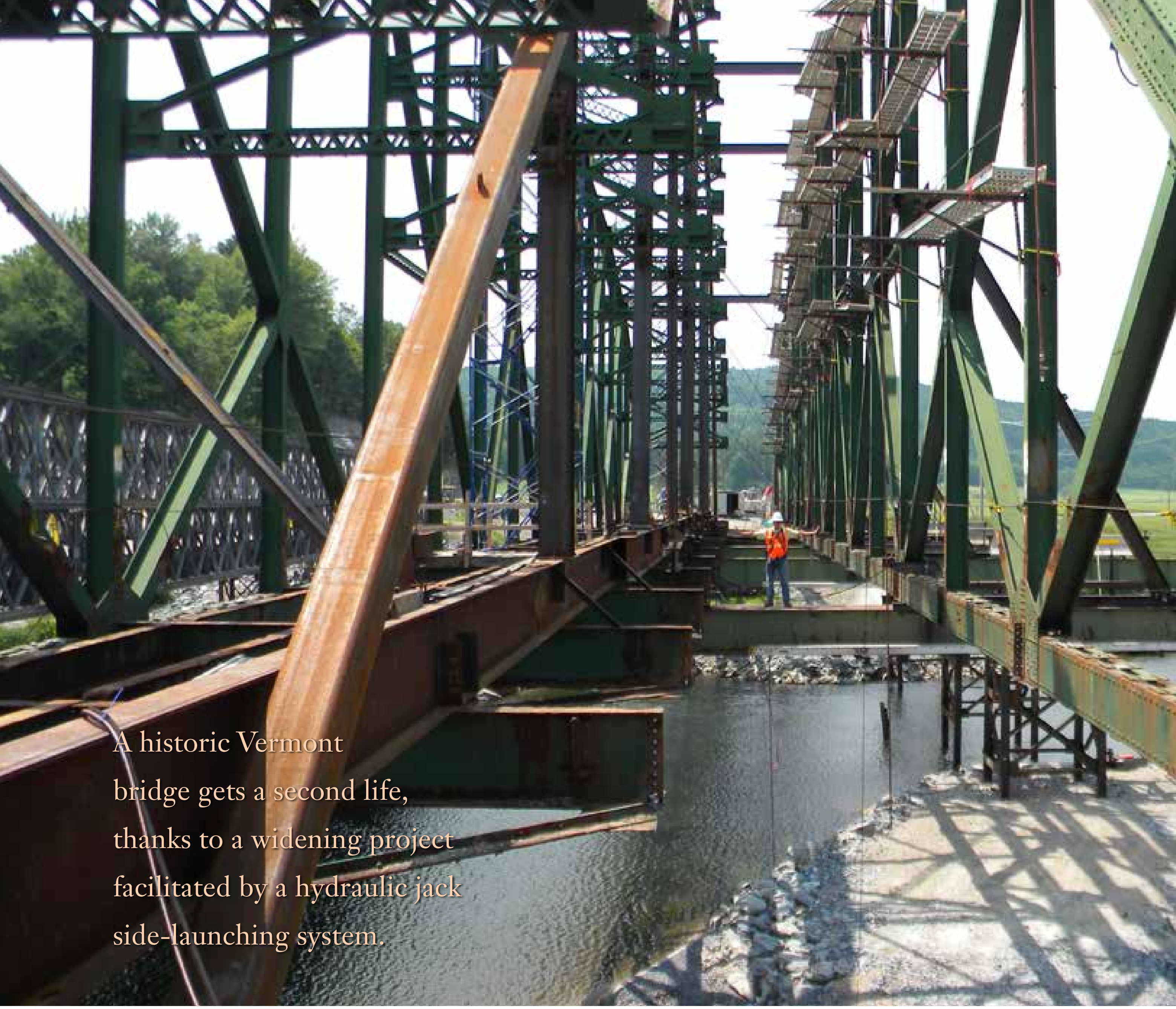
Steel Team

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

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

A Midas Civil model of the 322-ft-section.





Wider Load

BY JERRY PFUNTNER, P.E.

WHEN THE HISTORIC, 350-ft-long steel truss Checkered House Bridge was built in 1929 across the Winooski River in Richmond, Vt., it replaced yet another historic bridge: an 1800s-era wooden covered bridge that was severely damaged in the Great Flood of 1927.

Over time, however, the massive steel structure had been restricted to increasingly lower load limits. This eliminated a major and convenient option for commercial trucks to service the area—just minutes from Burlington in Chittenden County, the most populated county in the state—for nearly two decades.

After considering various alternatives and public input, the Vermont Agency of Transportation (VTrans) decided to keep the bridge in place and upgrade it to modern standards, which included expanding the curb-to-curb width from 20 ft. to 30 ft.

"The steel trusses are in very good shape, except for the flooring members and decking, so it still has a significant life span," explains Carolyn Carlson, structures project manager with VTrans. "Being able to reuse the bridge for its original intent in its original location definitely came into play."

Carlson has been involved with this bridge since 1990, when the concrete deck was originally considered for replacement. She notes that this is the first time a steel truss bridge of this magnitude has been widened by separating a truss and reattaching it using new steel supports. The project also marks VTrans' second


Jared Katz


Jared Katz

▲ The curb-to-curb width of the bridge was expanded from 20 ft. to 30 ft.

◄ The entire north truss chord was moved 12 ft, 6 in.

▼ Ten specially designed 18-in. stroke capacity hydraulic ram systems were placed on the top and bottom chords and at each abutment, and provided carefully monitored constant pressure to nudge the 65-ton north truss on Hilman rollers to its new location.


Fitzgerald & Halliday, Inc.


Fitzgerald & Halliday, Inc.

design-build project ever and includes the reconstruction and realignment of Route 2, Kenyon Road and Johnnie Brook Road.

The Checkered House Bridge is the state's only Pennsylvania through-truss bridge, which is based on the Pratt truss and characterized by half-length struts or ties in the top, bottom or both parts of the panels. "Part of the challenge was to be able to clearly delineate the original, aged, green historic steel members from the new ones—similar to small homestead farmhouses with distinct additions over time that dot the Vermont landscape," Carlson says. "Rather than a symmetrical look that mimics the original design, there is a visible distinction that preserves and adds to history at the same time."

The design-build team of CHA and Harrison and Burrowes brought in Tallahassee-based Finley Engineering Group (FINLEY) early in the bid process. "Due to the historical significance of the bridge, we had to develop a way to preserve as much of the original truss as possible, maintaining all portals and sway frames, while widening the structure and increasing load carrying capacity," says David Vieni, P.E., project engineer with CHA. The FINLEY-designed jack and roller side-launching system allowed the team to save 80% of the original truss,

Jerry Pfuntner is project manager for Finley Engineering Group in Tallahassee, Fla., an engineering firm with specialized expertise in complex bridge projects. Pfuntner conceptualized and developed the specialized falsework and hydraulic launching system for the Checkered House Bridge. He can be reached at **jerry.pfuntner@finleyengineeringgroup.com**.

All photos this spread: Jared Katz

The bridge, before the separation.

Erecting the new steel. Approximately 120 tons were added.

reducing the need for additional steel. The 36-month, $13.9 million project is on schedule to have the bridge open for traffic in June 2013. Approximately 120 tons of new steel was added for the widening project.

Hydraulic Help

FINLEY developed and implemented the concept to widen the truss bridge by cutting and carefully moving the entire north truss chord 12 ft, 6 in. To maintain the historical integrity of the original bridge, nearly all of its steel members were retained and new structural bracing members were installed within the widened portion only.

The innovative falsework and jacking system allowed the north truss to be moved, with lateral support being provided from the south truss system. The south truss was designed to support the entire existing truss bracing members with the aid of the falsework system, which stabilized the eccentric self-weight, wind loading and jacking forces through the many phases of the north truss jacking operation.

The hydraulic side-launch jacking system also helped transport the north truss, facilitated fit-up of the new bracing members and provided a means to adjust the camber of the north truss. The side-launching was completed in 1.5 days, achieving a launching rate of 2 ft per hour.

"When we got started on the project, FINLEY visited the site and proposed the cut and launch idea to the project team," explains Mark Klingbeil, vice president of operations with Harrison and Burrowes. "We all worked together to tweak the concept, and then Jerry went to work on the design and construction sequencing for the move of the north truss."

"There was nothing easy about this project," he continues. "We had to work with old shop drawings that could not be verified until we actually disconnected the north truss. In the end, the old drawings turned out to be fairly accurate and the fit-up pretty routine with the help of the hydraulic rams."

A team of 25 people from the design-build team were all on-site the day of the big move to carefully monitor 10 critical connection points that, when cut free, would expose the truss to potential distortion and twisting. Four transverse beams on both the upper and lower chords were the workhorses for stability for the north and south trusses. Once supports were in place, the north truss was cut free by removing bolts and rivets.

Ten specially designed 18-in. stroke capacity hydraulic ram systems were placed on the top and bottom chords and at each abutment, and provided carefully monitored constant pressure to nudge the 65-ton north truss on Hilman rollers to its new location. Movement had to be carefully orchestrated, and the team had to advance the support brackets for the jacks with every 12 in. of movement.

After doing the heavy work of moving the north truss into position, FINLEY's launching system was kept on-site to help make minor adjustments to get everything in line for the reconnection of the new steel with the relocated north truss. "As we installed new members, we could remove temporary support members," explains Klingbeil.

A team of 25 people from the design-build team were all on-site the day of the big move to carefully monitor 10 critical connection points that, when cut free, would expose the truss to potential distortion and twisting.

The new steel members were installed within the widened portion only to join the two chords in a distinctly visible way, and the corroded floor beams and stringers were replaced. Incorporating the new sections of the structure with the old members was complex. The temporary works design called for clamping existing members with bracketing connections to preserve the old steel members' integrity and used post-tensioning bars to apply a clamping force.

The project team concurs that the design-build process was key to this project's success. It allowed the team to work closely together using creativity and innovation to develop the best design and construction approach to meet the owner's needs in the most effective and safest manner, while providing the optimum value for taxpayers.

"It was like a big puzzle, putting together lots of pieces," recalls Vieni. "There was a lot of anticipation of what could go wrong. In the end, there wasn't a lot to talk about, thanks to the efforts of all involved, and that is a good thing." MSC

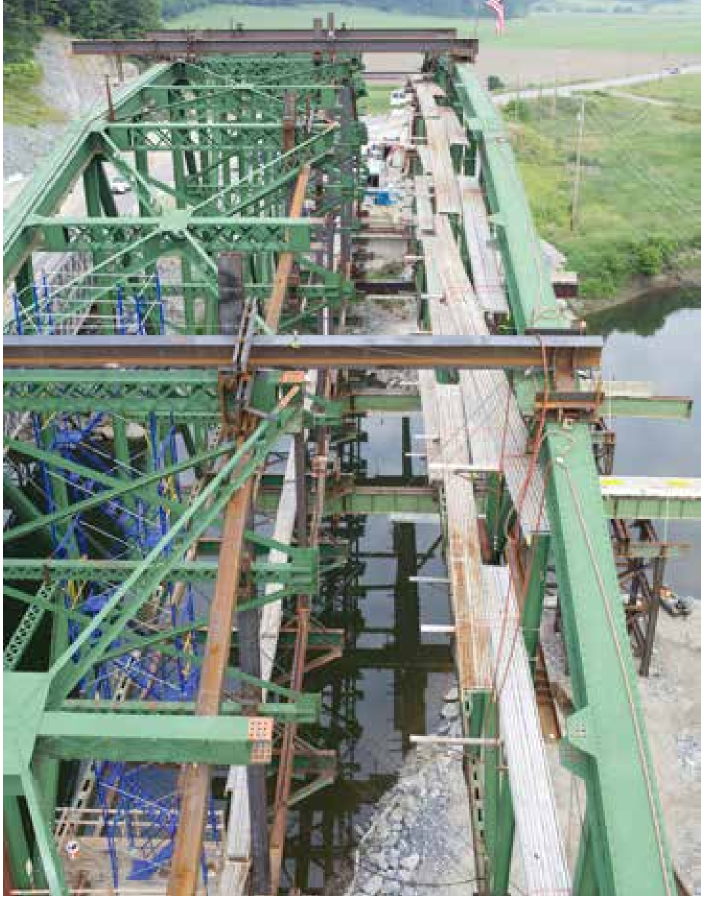
Owner
Vermont Agency of Transportation

Structural Engineers
Finley Engineering Group, Tallahassee, Fla.
CHA, Albany, N.Y.

General Contractor
Harrison and Burrowes, Glenmont, N.Y.

Steel Team

Steel Fabricator
STS Steel, Inc., Schenectady, N.Y. (AISC Member/AISC Certified Fabricator/NSBA Member)



▲ The side-launching was completed in 1.5 days, achieving a launching rate of 2 ft per hour.

▼ New top members.

A steel network tied arch serves as the successor to a 1930s steel truss honoring the famous female flyer.

Replacing Amelia's Bridge

BY FRANK BLAKEMORE, P.E., AND NATALIE MCCOMBS, S.E., P.E.

MANY KNOW THE STORY of Amelia Earhart, best known for being the first female to fly solo across the Atlantic Ocean and later attempting a flight around the world at age 40. But likely few know the pioneering pilot was a native of Atchison, Kan., where a bridge named after her flew traffic over the Missouri River for 74 years.

The steel through truss, built as a Works Progress Administration (WPA) project in 1938, had been nursed through nearly 10 rehabilitations before the decision was made to replace it in 2002. Its shoulderless, narrow roadways fell short of 21st century needs. And the condition of its deck trusses worried the owners.

Because the bridge was a beloved, historic structure, both the Kansas and Missouri Departments of Transportation (KDOT and MoDOT) knew the community would have a significant voice in selecting the new design. In fact, citizens already had made one thing clear: The new bridge would be made of steel, like its predecessor.

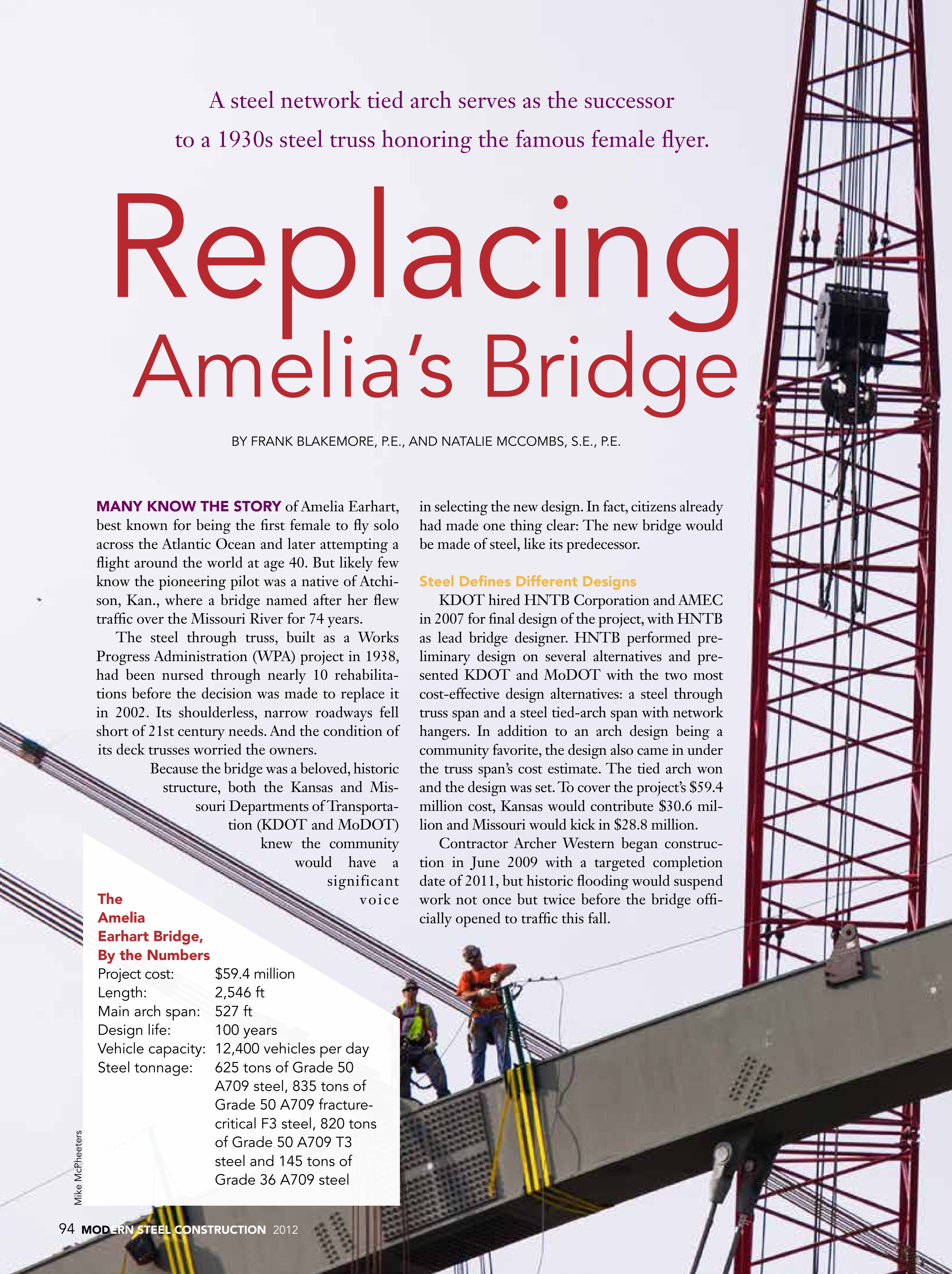
Steel Defines Different Designs

KDOT hired HNTB Corporation and AMEC in 2007 for final design of the project, with HNTB as lead bridge designer. HNTB performed preliminary design on several alternatives and presented KDOT and MoDOT with the two most cost-effective design alternatives: a steel through truss span and a steel tied-arch span with network hangers. In addition to an arch design being a community favorite, the design also came in under the truss span's cost estimate. The tied arch won and the design was set. To cover the project's $59.4 million cost, Kansas would contribute $30.6 million and Missouri would kick in $28.8 million.

Contractor Archer Western began construction in June 2009 with a targeted completion date of 2011, but historic flooding would suspend work not once but twice before the bridge officially opened to traffic this fall.

The Amelia Earhart Bridge, By the Numbers

Project cost:	$59.4 million
Length:	2,546 ft
Main arch span:	527 ft
Design life:	100 years
Vehicle capacity:	12,400 vehicles per day
Steel tonnage:	625 tons of Grade 50 A709 steel, 835 tons of Grade 50 A709 fracture-critical F3 steel, 820 tons of Grade 36 A709 T3 steel and 145 tons of Grade 36 A709 steel



Mike McPheeters

The new U.S. 59 Amelia Earhart Bridge, a four-lane, ample-shouldered network tied-arch bridge, rests just 78 ft south of the old bridge. Approximately 2,546 ft long, the structure consists of 2,019 ft of 78-in. NU (Nebraska University) prestressed concrete I-girder approach spans and a 527-ft steel tied-arch main span.

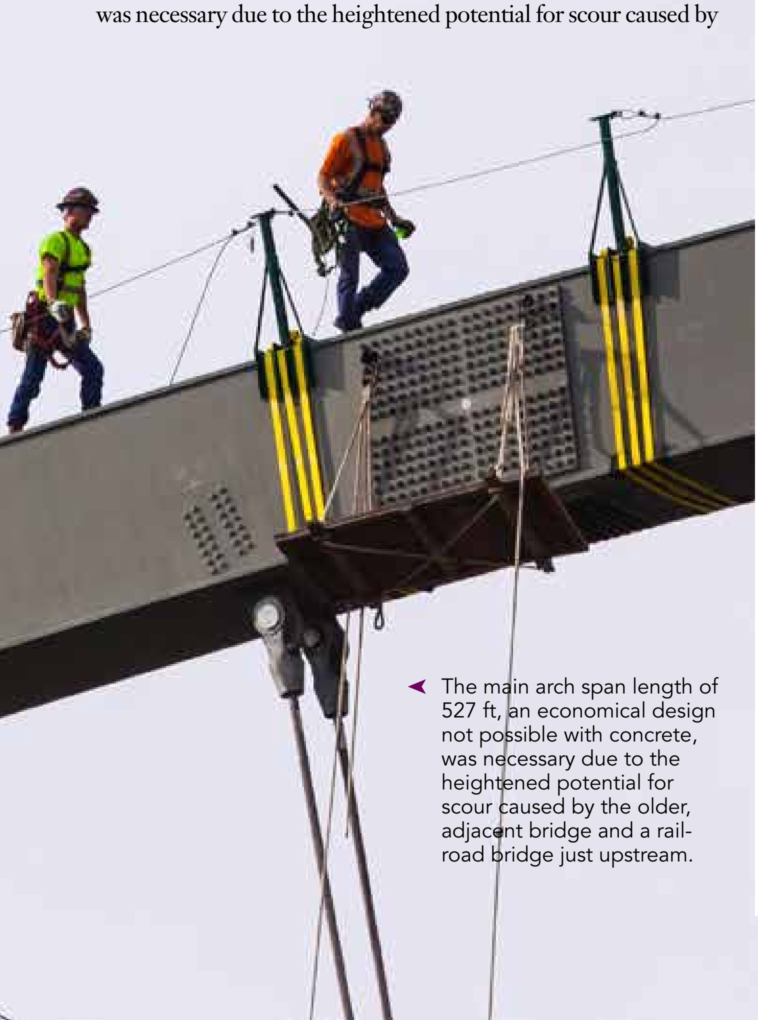
The new bridge has a 100-year design life and is capable of handling the 20-year traffic projections of 12,400 vehicles a day, twice the capacity of the previous bridge. The former bridge, kept open to traffic during construction, will be closed once traffic is shifted to the new bridge and will be demolished next year.

Steel suppliers, including Nucor-Yamato, SSAB and Arcelor-Mittal, shipped approximately 2,280 tons of Grade 50 A709 steel and 145 tons of Grade 36 A709 steel to fabricator Industrial Steel Construction. Fracture-critical F3 steel was used for tension members and T3 steel was designated for bending members.

When it came to constructability, the steel design facilitated construction in three ways:

- Falsework was kept to a minimum.
- The contractor, Archer Western, had the option of constructing the main arch span off-site, floating it in and lifting it into place or constructing the span over the river. (Because Archer Western had erection towers from a previous project, the span was built on-site as it was the more cost-effective option.)
- For the on-site option, crews could cantilever the steel erection over the navigation channel, which kept the river open to traffic during construction.

Steel also offered a greater span length. The main arch span length of 527 ft, an economical design not possible with concrete, was necessary due to the heightened potential for scour caused by



The main arch span length of 527 ft, an economical design not possible with concrete, was necessary due to the heightened potential for scour caused by the older, adjacent bridge and a railroad bridge just upstream.

Mike McPheeters

The bridge uses approximately 2,400 tons of steel.

Mike McPheeters

A marker on the Missouri Riverfront in downtown Atchison commemorates the Lewis and Clark expedition's visit to the area.

Mike McPheeters

Fracture-critical F3 steel was used for tension members and T3 steel was designated for bending members.

Frank Blakemore (fblakemore@hntb.com) is a project manager with HNTB. He has 18 years of structural engineering experience, including the design of cable-stayed bridges, steel arch bridges and post-tension box girder bridges. **Natalie McCombs** (nmccombs@hntb.com) is a bridge engineer at HNTB. She has 11 years of bridge design experience, including the design of tied-arch bridges, a deck-arch bridge and a cable-stayed pedestrian bridge.

The new bridge has a 100-year design life and is capable of handling the 20-year traffic projections of 12,400 vehicles a day, twice the capacity of the previous bridge.

the older, adjacent bridge and a railroad bridge just upstream. Steel also made it possible to achieve the required 52-ft vertical clearance over the river. (Concrete might have been applicable here but only if used in a more expensive cable-stay design.)

In terms of aesthetics, several aspects of the new bridge are references to either the original truss or to Amelia Earhart. The X-bracing between the ribs was chosen to provide a visual connection to characteristics of the earlier historic truss form. In addition, pier caps exhibit the rounded wing shapes of the planes Amelia flew in her day. At the community's request, designers added high-intensity beam luminaires to the arch portals, echoing the previous bridge's aesthetics. These twin beams of light cast an eternal gaze into the night sky and symbolize Earhart's passion for flying. Additionally, LEDs (light-emitting diodes) with changeable colors were provided along the top edge of the arch ribs to commemorate holidays, special events, and draw attention to the structure. Light poles and light fixtures were also selected by the community to tie in with the historic downtown.

A Springboard for Innovation

The designers were able to introduce several safety and cost-saving innovations to the steel tied-arch design:

Creating internal redundancy. Two main force-carrying components exist in the tied-arch system:

1. The arch ribs follow a parabolic curve, rising 90 ft above the driving surface for a span-to-height ratio of 5.83. The arch rib is a 4-ft wide by 4-ft, 6-in.-high welded box section, which allows for internal inspection of the arch rib and upper hanger connections.
2. The tie girder is a 4-ft-wide by 6-ft-high bolted box section between the ends of the arch ribs and contains the lower hanger connections. The bolted box section increases safety by internal redundancy.

Because tie girders carry tension and a loss of these members would result in catastrophic structural failure, tie girders are classified as fracture-critical. This weakness prompted a Federal Highway Administration (FHWA) advisory in 1978, recommending tie girders have redundant tie members. Since that advisory, few tied-arch spans have been designed until recently.

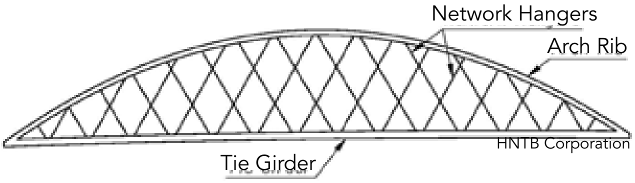
Engineers on the project addressed the FHWA advisory's concern by separating each tie girder plate. To create the necessary internal redundancy, the flanges were bolted to the webs, using 8-in. by 8-in. angles. If a crack were to occur in either flange or web, it would not continue through the adjacent plates and result in loss of the entire section.

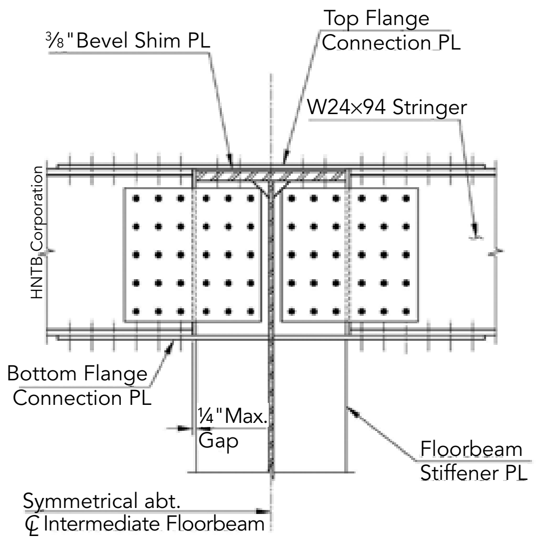
Network hanger system increases redundancy. During the preliminary design phase, designers compared a network hanger system to a vertical hanger system and discovered the network hanger system provided increased redundancy, improved public safety and offered a 3% cost savings.

A network hanger system increases redundancy by connecting two hangers to the tie girder at the same point and angling them away from each other (Figure 1), so they attach to different locations on the arch rib. Using this technique, forces from a hanger loss are distributed to the adjacent hanger, and the tie girder still is supported at the hanger location.

The hangers used on the network arch of the new bridge are ASTM A586 pre-stretched bridge strand.

Figure 1: Network Hanger System





▲ Figure 2: Stringer-to-Floorbeam Connection

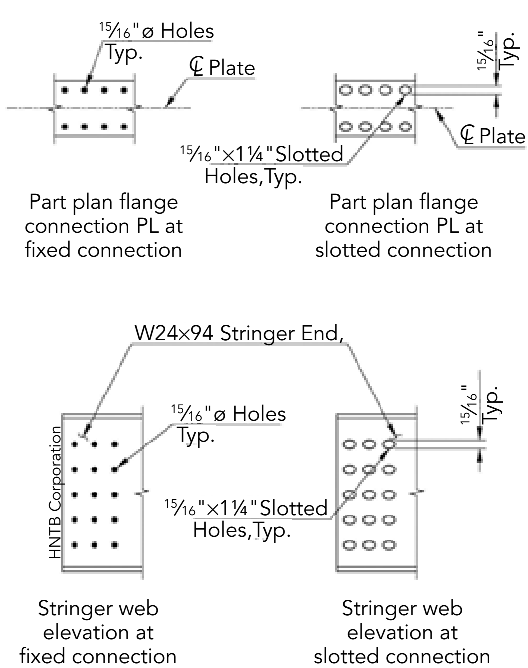
▲ The final arch rib, complete with topping out tree, being
▼ lifted into place.

Knuckles are critical to thrust transfer. The knuckle is where the tie girder and arch rib join, a critical component of a tied-arch design. Because the flanges in this region are discontinuous, the web plates are the critical link and must be able to transfer the arch thrust force to the tie girder. For the Amelia Earhart Bridge, the knuckle consists of 2¼-in. web plates on each side of the arch rib.

With the knuckle connections' complex geometry, using angles to connect the tie girder flanges to the knuckle web plate was not an option. Instead, crews welded a vertical tab plate to the top and bottom flange plates to allow bolting to the knuckle web plate. Because the knuckle is capable of carrying the entire tensile force in the web, shear lag effects had to be considered in the transition to the tie girder box shape.

Stringers framed into floorbeams address clearance restrictions. One of the biggest initial design challenges was securing the vertical clearance of approximately 52 ft over the river. The grade on the Atchison side of the new bridge was fixed because of an existing intersection, so designers had to reduce the superstructure depth as much as possible. To achieve this, they framed the stringers into the floorbeams so that the top of the floorbeam and the top of the stringer align (Figure 2). By comparison, a typical arch floor system uses stringers running atop the floorbeam.

▼ Figure 3: Stringer and Connection Plate End Connection Details



In coordination with the framed-in stringer concept, designers detailed the stringer-to-floorbeam connections with slotted holes in one ply of the flange connection plate and the web (Figure 3). The slotted holes occur at every other floorbeam and allow the structure to elongate (bolts are only finger-tight) during erection and slab placement without inducing axial forces into the stringers under dead load. This allows the arch to deflect into shape with the placement of the deck. After the majority of the slab placement occurs, bolts in the slotted connections are fully tightened.

The resulting floor system of the new Amelia Earhart Bridge consists of floorbeams spaced at 15-ft intervals, corresponding to the location of the hangers with stringers spaced 8 ft, 3 in. apart. The intermediate floorbeams are 6-ft I-beam sections at

Mike McPheeters

The final arch rib, in place.

the tie girder, with the top flange following the deck's slope. They are connected with 24-in. rolled beam stringers. The end floorbeam is a welded box section.

The new Amelia Earhart Memorial Bridge is the gem of the Atchison skyline—a signature structure that pays homage to its precursor and serves as a tribute to one of America's greatest pilots. MSC

Owners

Kansas Department of Transportation and Missouri Department of Transportation

Structural Engineer

HNTB Corporation, Kansas City

General Contractor

Archer Western, Chicago

Steel Team

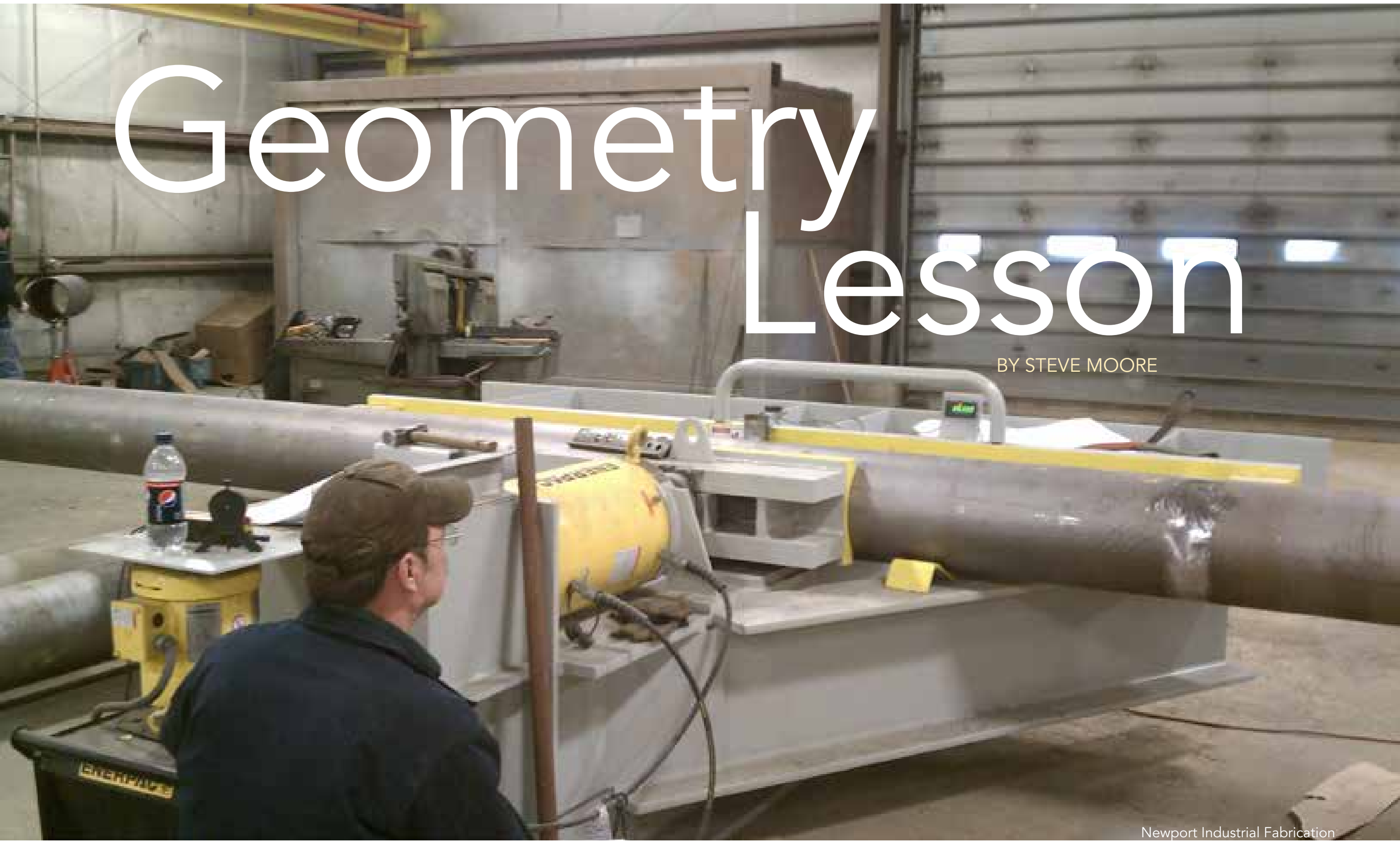
Fabricator

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

Steel Detailer

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

Complex geometry and an equally complex site drove the design of a new pedestrian bridge project in Boston.



Geometry Lesson

BY STEVE MOORE

Newport Industrial Fabrication

▲ Bending the 12-in. main chords.

THE NORTH BANK BRIDGE takes quite the winding path.

Built to connect isolated sections of Boston's pedestrian park system, the bridge was faced with a number of geometric constraints that forced it to snake over, under and through a maze of existing facilities along the north bank of the Charles River, including a commuter rail yard, the Leonard P. Zakim Bunker Hill Memorial Bridge, a historic building, two highway ramps and a boat ramp.

The 10-ft-wide bridge, which spans nearly 700 ft and provides a bike and pedestrian connection between Cambridge and Charleston, Mass.—both of which are across the Charles from Boston—was conceived in conjunction with the massive Central Artery/Tunnel Project. Funded by the American Recovery and Reinvestment Act (ARRA) and administered by the Massachusetts Department of Transportation (MassDOT), it would be one of the most geometrically complex structures associated with that project. The resulting design consisted of pipe trusses whose deck chords would follow the general S-shaped centerline, while its outer chord undulated above and below the deck, creating a structure with the appearance of a bent strand of DNA. The general contractor, Barletta Heavy Division, chose Newport Industrial Fabrication as the fabricator and Saugus Construction as the erector, and the team retained Civil Geometrics to handle the project's challenging geometry.

Before fabrication could begin, the structure's exact geometry had to be defined mathematically. The basic shape had been provided by the structural designer (Ammann and Whitney) as a series of work point coordinates, but a number of details had to be refined in order to develop complete shop drawings. The team developed a CAD model that respected the design intent while considering issues related to materials use, ease

Steve Moore is the sole proprietor of Civil Geometrics and provides survey and geometric support services to the design, fabrication and heavy construction industries. You can reach him at **smoore@civilgeometrics.com**.

Steve Moore

The bridge being erected on the north bank of the Charles.

One of many diagonals displaying compound fish-mouthing.

Newport Industrial Fabrication

Newport Industrial Fabrication

of fabrication, welding codes and the erection process. When finished, this model would drive every aspect of fabrication and erection of the structure.

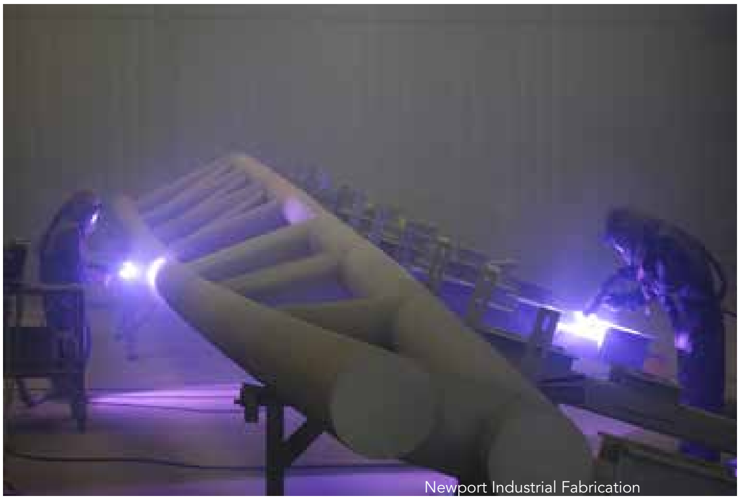
Bizarre Bends

One of the biggest challenges was determining how to bend the 12-in. hollow structural section (HSS) main chords that trace bizarre corkscrew-like curves in three dimensions. Using custom software provided by Civil Geometrics, these four 700-ft chords were parsed for manageable (10-ft to 40-ft) sections whose local curvature was virtually planar. This allowed these segments to be bent as flat (2D) curves and the desired 3D shape would be achieved by appropriate "timing" of these segments relative to each other. The steel bending was performed by Newport Industrial Fabrication, which actually designed and built its own bending machine. Further work by Civil Geometrics provided curve ordinates for each phase of the bending of the many chord segments. The remaining truss elements (12-in. HSS verticals and 6-in. diagonals) provided an additional challenge requiring the computation of hundreds of parameters defining their geometry. Because of the non-planar nature of the trusses, as many as ten parameters were required to define the "fish-mouthing" of the most complex members, with no two ever being the same. Most challenging were the diagonal braces that overlapped both the main chords and the vertical members. Parameters included length, four intersection angles, three "timing angles" and two offsets relating the diagonals to the verticals. Performing the welding of these joints in a code-compliant manner, while maintaining the geometry, was a technical challenge that required both an in-depth analysis of dihedral angles on a one-off basis and Newport Industrial's highly skilled welders—as well as MHP Systems Engineering, Houston, who acted as the TYK weld consultant. All full-penetration welds were inspected with MT or UT.

Defining the mathematics of the trusses was only the first step in getting the structure's geometry to come together properly. In order to control and monitor this geometry, a method of precise survey control had to be established in the shop. For this purpose, Newport Industrial acquired a high-precision total station. This is a standard piece of survey equipment that combines the ability to measure angles and distances with an onboard computer and the ability to store large amounts of data. Working with Civil Geometrics, Newport established a network of 14 permanent survey targets around the work area. Repeated surveys established the relative positions of these targets to sub-millimeter accuracy, and they became the frame of reference used to lay out and monitor the fabrication process. Resection techniques then allowed the total station to be positioned anywhere on the shop floor and to control the structure's geometry to the high degree of accuracy required.

Pre-asssembly work in the fabrication shop yard.

The first stage of fabrication, with trusses positioned for ease of access and welding.



Thermal zinc coating being applied at Newport Industrial's coatings facility.

Pieced Together

For transportation and erection, the bridge was divided into nine separate assemblies, and the fabrication of each of these was performed in three stages. In the first stage, the "north" and "south" truss assemblies were positioned on pipe stands and oriented on the shop floor for convenient access and welding. This required that global coordinates defining the truss geometry undergo a "rigid body transformation" to the preferred shop position and orientation. As fabrication was done with the trusses in an entirely different orientation from what their final position would be, the geometry of each assembly, in the form of X/Y/Z coordinates, had to be manipulated to conform to the shop's frame of reference. Working with Newport's engineers, Civil Geometrics provided the transformed coordinates for each truss position on the shop floor. With this information in hand, the total station could be used to position every component of the trusses to a very high degree of precision and to monitor them as fabrication progressed.

In the second stage, the north and south trusses for each assembly were repositioned so as to relate properly to each other, and the HSS10×6 floor beams were added completing each of the nine assemblies. As in the first stage, a transformed set of coordinates, representing the proper shape of each assembly in this new position, had to be provided.

In the third and final fabrication stage, adjacent pairs of assemblies were positioned outside of the shop to ensure their proper relationships. Connections were fine-tuned in this stage and any minor surplus or deficit in length was noted so that adjustments could be made in subsequent assemblies. A final as-built survey of the base plates and critical nodes served to review the geometry achieved and to provide guidance for the erection process.

As with the fabrication of the superstructure, the construction of the abutments and piers that would carry the bridge also had to be controlled closely. As with the survey work in the shop, a frame of reference had to be established that had the geometric integrity demanded by such a project. Working with Civil Geometrics, Barletta's survey team recovered approximately ten existing survey monuments originally provided for the Central Artery/Tunnel project and incorporated these into a local survey network, along with 12 additional points added in stable and convenient locations. Processing the highly redundant survey data then produced a network that could be used to locate all substructure components of the project. Upon completion of this work, a careful as-built survey was performed and compared to the 3D model of the superstructure to ensure that there would be no surprises when it came time to erect the trusses.

Getting There

For trucking, each of the nine sub-assemblies was carefully cross-braced, then split in two lengthwise by cutting all of the HSS floor beams at their midpoints. A total of 18 permit loads delivered these pieces to the job site, where they were reassembled into the original sub-assemblies. To control the erection of certain components, Civil Geometrics performed reverse coordinate transformations of shop as-built geometry back to the project's global coordinate system. This allowed Barletta's surveyors to position those truss ends that were supported on falsework at mid-span locations.

Through careful planning and a lot of intricate engineering and survey work, the North Bank Bridge, which opened this past summer, came together virtually flawlessly and takes its place as a critical link in Boston's pedestrian park system. MSC

Owner
Massachusetts Department of Transportation

Structural Engineer
Ammann and Whitney, Boston

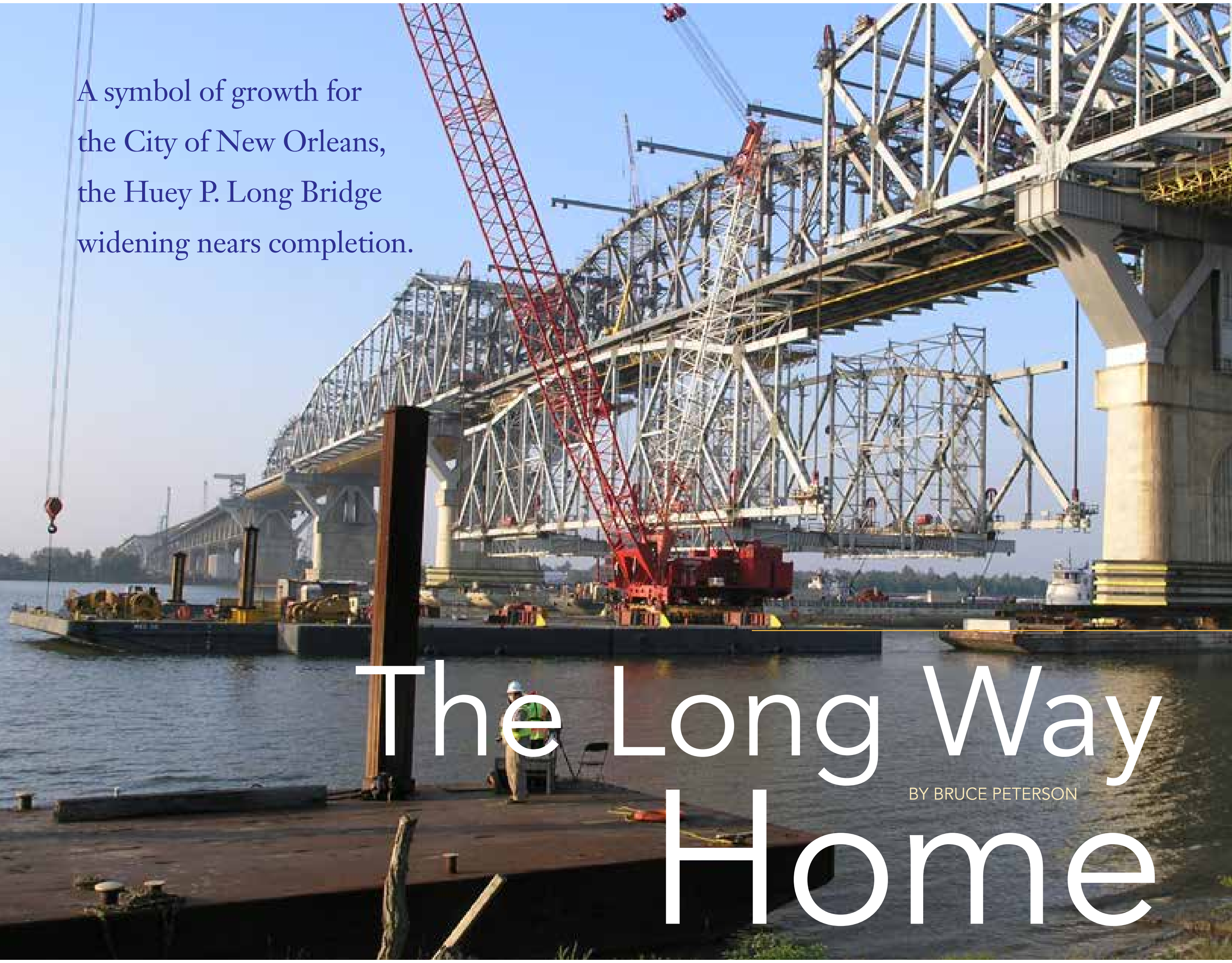
General Contractor
Barletta Heavy Division, Canton, Mass.

Survey/Geometric Design
Civil Geometrics, Bozeman, Mont.

Steel Team

Fabricator
Newport Industrial Fabrication, Newport, Maine (AISC Member/AISC Certified Fabricator/NSBA Member)

Erector
Saugus Construction, Georgetown, Mass. (AISC Member)



A symbol of growth for the City of New Orleans, the Huey P. Long Bridge widening nears completion.

The Long Way Home

BY BRUCE PETERSON

THE HUEY P. LONG BRIDGE has been vital to the economy of New Orleans and Louisiana for more than seven decades.

One of the first Mississippi River spans built in Louisiana, the cantilevered steel through truss bridge has been carrying both rail and highway traffic across the Mississippi River, just outside of New Orleans, and facilitating economic growth for the city since it was completed in 1935. While it shares a rich history with New Orleans, its most important role lies ahead.

During the 1930s, the bridge was built to carry both rail and highway traffic, which was relatively common at the time. At 23,000 ft between railroad abutments, the main spans included 9-ft highway travel lanes cantilevered off of the railroad bridge. Today, the bridge remains an important artery for both forms of traffic, and until recently the original 9-ft highway traffic lanes were still in use by motorists. With traffic volumes continuing to increase at this vital crossing of the Mississippi River, however, additional traffic capacity was needed.

In 1982, a study was conducted for a new bridge crossing on a nearby alignment. Five alternatives were studied, but due to the large amount of right-of-way required on either side of the bridge—coupled with the inherently high costs associated with a major river crossing—a new crossing was not considered a viable option. Additionally, despite the fact that the public wanted and needed additional highway capacity across the river, numerous public meetings all resulted in the same conclusion: No agreement could be reached on a location for new river crossing. Consequently, in 1986 the Louisiana Department of Transportation and Development (LADOTD) decided to investigate widening the existing span in order to provide the needed highway capacity on the existing traffic corridor.

Modjeski and Masters, the structural firm that designed the original bridge, was engaged to design its update. The first major challenge was to address whether or not soils could support the increased load. The bridge's foundation is a caisson founded on deep sand layers located below the typical compressible clay layers found at the surface. Fortunately, the geological investigation determined that these deep sand layers could support the additional loads of a widened bridge.

All photos: Modjeski and Masters

▲ The bridge has gone from two 9-ft lanes to three 11-ft lanes.

◄ A system of steel "W" frame pier caps support the truss lines for the new lanes.

► A view of the new truss line system.

Innovative Support

Once the soil was deemed adequate to support the increased foundation loads, plans for the Huey P. Long Bridge Widening project could begin. 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. To achieve this, the design used a unique steel "W" frame pier cap expansion supported on a concrete encasement of the lower portion of the existing pier. This expanded pier cap was needed in order to support the additional truss lines that would be used to support the new lanes. The combined total weight of the steel pier caps used for the widening project is nearly 4,750 tons, just under 1,000 tons per pier.

Construction began in April 2006 and with a final construction cost of approximately $1.2 billion, it has become the largest construction project in Louisiana's history. The first phase of the seven-year, four-phase project involved widening of the main support piers. Four concrete river piers and one land pier were widened by encasing the lower portion of the existing piers with concrete. The encasement began at the top of the caisson distribution block and extended up approximately 97 ft. This encasement, which widened the piers from 60 ft to 80 ft, supported a new steel frame that was, in turn, used to support the widening trusses, which enabled the widening

Bruce Peterson is a senior associate at Modjeski and Masters. You can reach him at **bepeterson@modjeski.com**.

of the main river spans. The 53-ft-tall steel frame, which was commonly referred to as the "W" frame due to its appearance, is 152 ft wide at the top, but only 75 ft wide at its bearings on top of the encasement.

The second phase of the work modified portions of the existing railroad approaches so that the new, wider highway approaches could pass through them. Modifications to the existing railroad trestles were necessary on both sides of the river. On the west bank, one of the existing steel towers had to be removed to permit new at-grade roadways to pass traffic to the other side of the railroad trestle. Two straddle bents, consisting of concrete columns supporting a steel box girder, were designed to support the existing railroad superstructure. Special bearings were designed to permit the box girder to behave as a simple beam and at the same time resist "rolling over" as a result of railroad longitudinal forces.

As the interruption of railroad traffic had to be kept to a minimum, the removal of the existing tower, the erection of the steel box girder and the restoration of rail traffic had to be done within a 24-hour closure period. Like the west bank, a portion of the east bank trestle conflicted with the new roadways, but on the east bank two trestle towers had to be removed and the existing railroad superstructure replaced with longer girder spans, which were supported on concrete straddle bents. Again, the interruption of rail traffic had to be minimized for this work, but as there are two tracks, one could allow rail traffic to continue while the new longer superstructure was erected on the other.

The third phase was the widening of the main bridge. One of the most difficult challenges of this phase was the requirement to maintain highway, rail and marine traffic throughout construction. While short outages could be arranged, longer interruptions were not possible. The most difficult issue was highway traffic. The original bridge supported two lanes of highway traffic on an 18-ft-wide roadway supported by a floor beam bracket cantilevered from the outside of the existing trusses, while the new wider roadway would be supported on a floor beam that would span 50 ft between the existing and widening trusses. Swapping one for the other would typically require closing the roadways. The problem was solved by incorporating the original floor beam bracket into the widening floor beam, thus permitting highway traffic to continue to use the original roadway while widening construction was performed. Highway traffic impacts were further minimized when the contractor, MTI (Massman, Traylor, and IHI), along with HNTB (who performed the construction engineering for MTI), developed an alternative method of erection that permitted three 530-ft-long sections of the widening trusses to be erected at one time as opposed to erecting them one individual member at a time. For this erection, an upstream and downstream section of the widening trusses, braced with a stability frame, were floated on barges to the bridge, and then both widening trusses and stability frames were hoisted into position by the constructor's team using strand jacks. This approach minimized both

The widening project involves the addition of more than 22,000 tons of new steel.

vehicular and marine traffic impacts during construction. (See "Lift, Slide, Attach, Repeat" in the 09/2010 issue for more on this erection scheme.)

Approaches Approaching

The fourth and final phase, estimated for completion next August, involves construction of new approaches. As of this past spring, a portion of the new roadways were opened to traffic, while construction teams continue to remove the old lanes and replace them with the remaining sections of the final widened roadway. When completed, phase four will ultimately complete the replacement of the original two 9-ft lanes with three 11-ft lanes, adding the shoulders, demolishing the old approaches and main deck and adding signaled intersections and approach ramps at either side of the bridge to improve flow and connectivity.

The widening of the Huey P. Long Bridge presented many unique design and construction challenges not often encountered in typical bridge design and rehabilitation projects. From maintaining highway traffic during the widening phases to using a construction method that resulted in large, truss segments being erected as complete units, the teams worked together to solve challenges that facilitated the continuous flow of traffic across the bridge for the duration of the project.

Today, the Huey P. Long Bridge Widening Project stands as a symbol of growth and rebuilding for the city of New Orleans, particularly during a time when economic expansion is critical for the region. At the completion of the project, it is estimated that more than 22,000 tons of new steel will be added for the main span widening alone. MSC

Owner
Bridge: New Orleans Public Belt Railroad
Highways: Louisiana Department of Transportation and Development

Structural Engineer
Modjeski and Masters, New Orleans

Construction Manager
Louisiana TIMED Program

Erection Engineer (Main Bridge Superstructure)
HNTB, Kansas City, Mo.

General Contractors
Main Bridge Superstructure: MTI, a joint venture of Massman Construction Co., Kansas City, Traylor Brothers, Inc., Evansville, Ind. (AISC Member/AISC Certified Erector) and IHI Corporation
Approaches/Main Bridge Deck Widening: KMTC, a joint venture of Kiewit, Metairie, La., Massman and Traylor Brothers
Main Bridge Substructure: Massman
Railroad Modifications: Boh Bros. Construction, New Orleans

Steel Team

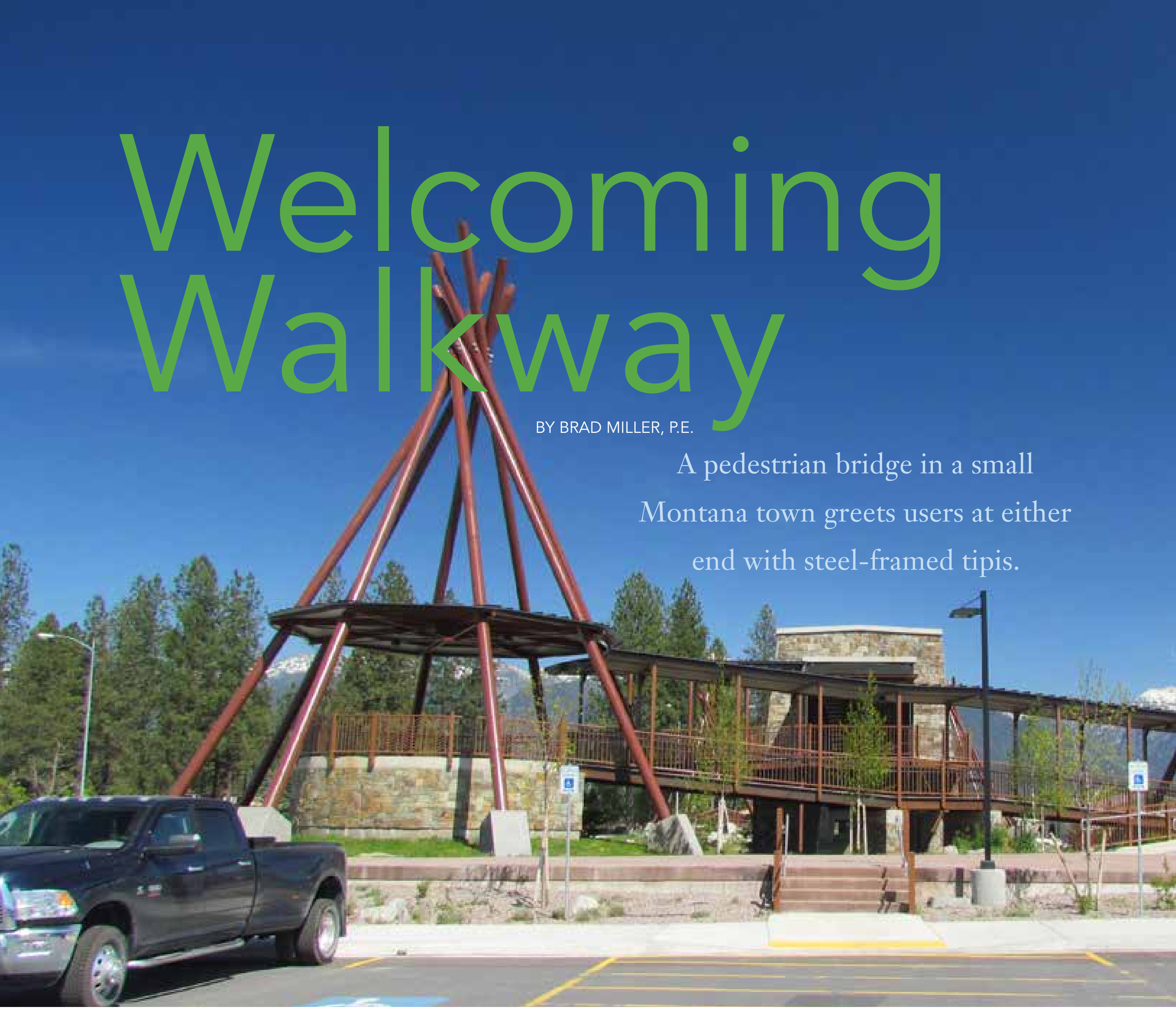
Fabricator
Industrial Steel Construction, Gary, Ind. (AISC Member/AISC Certified Fabricator/NSBA Member)

Detailers
Superstructure: Candraft Detailing, Inc., New Westminster, B.C. (AISC Member), and Tenca Steel Detailing, Quebec, Quebec (AISC Member)
Approaches: Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member/NSBA Member)

Welcoming Walkway

BY BRAD MILLER, P.E.

A pedestrian bridge in a small Montana town greets users at either end with steel-framed tipis.



THINGS ARE MOVING FASTER in the small town of Pablo, Mont., these days.

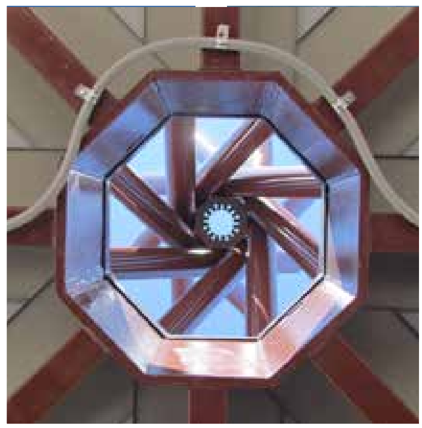
The reconstruction of Highway 93 into a new four-lane highway, which bisects Pablo, has increased traffic in the area and separates Salish Kootenai College from the town's central core. Crossing the roadway on foot or bike has become a more risky proposition, thus building the case for a new pedestrian overcrossing.

The answer came in the form of the Pablo Pedestrian Bridge, a $3.2 million project funded by the American Recovery and Reinvestment Act (AARA) that was built for the Confederated Salish and Kootenai Tribes (CSKT) and local residents in western Montana over Highway 93, which the tribes call the People's Way.

The Montana Department of Transportation (MDT), in conjunction with the Federal Highway Administration (FHWA), developed initial concepts for the overcrossing, including concrete and steel options. However, CSKT felt that the appearance did not fit into the surrounding environment and did not reflect their culture. MDT and FHWA therefore decided to give CSKT an active role in the design and construction process, as well as let them manage the project, and agreed to have MDT take ownership of the bridge and maintain it once construction was complete. HDR Engineering was chosen to design the project and assist CSKT in administering construction (construction cost for the project was $2.5 million, while the total cost, including engineering and administration, was $3.2 million).

Span and Ramp Development

Several designs were initially considered for the bridge: short-span, long-span and center-pier. Safety concerns, as well as anticipated construction and visual impacts, kept the center pier option from moving forward. And while the short-span option meant using less material, it too was eventually ruled out due to a MDT study revealing the high cost of moving adjacent utilities ($500,000) compared to the projected additional cost for a longer span.



▲ The tipi structures, two at each end, are 60 ft tall.

◄ Tipi roof with oculus framing the reciprocal frame top connection.

All photos this spread: Brad Miller

▲ Finished zigzag ramps and landings under tipi frames at each end of the bridge.

▲ Night placement of bridge span sections on falsework.

The long-span option was therefore chosen on this basis, with the added benefit of being deemed superior from an aesthetics standpoint. The final length of 265 ft allowed the bridge to adequately span the intersection without significantly impacting the adjacent utilities. About 150 tons of structural steel was used for the span, while the approach ramps and landings used 75 tons.

A prefabricated steel box truss (12 ft wide and 16 ft deep at mid-span) was chosen for the span. A timber deck was chosen over a concrete deck, as it allowed the use of 12-in. by 12-in. HSS for the truss chords; a concrete deck would have required approximately 16-in. by 16-in. truss chords. This option also allowed for the use of weathering steel, as 12 in. by 12 in. was the largest HSS size that was readily available in weathering steel at the time without having to use a special built-up section. Diagonal chords on the bridge truss are configured to match common tribal geometric patterns, and the cambered variable depth truss is reminiscent of a bow.

Brad Miller is a senior bridge project manager with HDR Engineering, Inc., in Missoula, Mont. You can reach him at **brad.miller@hdrinc.com**.

Brad Miller

Brad Miller

▲ An attractive, safer pedestrian route over Highway 93.

◄ Finishing the roof structures and flatwork.

Chris Kelly

▲ Tribal elders cutting the ribbon.

▼ The completed bridge, looking east.

Tom Hanou

For the ramp, multiple configurations were investigated and presented to CSKT, including circular and modified circular configurations, a zigzag configuration and switchback ramps. Each of the ramp configurations made use of raised landscaping on each side of the highway, reminiscent of the pine-studded sand dunes that are common to the area, in order to greatly reduce the length of elevated ADA ramps required. Four 30-ft-long ramps with a 1:12 slope and four horizontal landings were required. Sidewalks with a 5% maximum slope lead up to the base of the ramps to facilitate two-way pedestrian and bicycle traffic in various directions depending on the trails and building locations near the bridge. The zigzag configuration was eventually chosen because of its compactness and aesthetic considerations, and metal roofs were placed over the bridge, ramps and landings roofs to protect pedestrians and cyclists from the elements. The ramps were framed with wide-flange sections and channels, and HSS was used to frame the roofs.

Steel Tipis

Two tipi structures with exposed steel frames were located at the landings at both ends of the bridge, symbolizing the Salish and Kootenai tribes that coexist on the CSKT reservation. The four tipis are 60 ft high and are constructed from eight 12-in.-diameter HSS that form a reciprocal frame, a very simple and efficient structural configuration. A roof covers each tipi landing with a 22-in.-diameter oculus (rain hole) providing an upward view of the reciprocal frame top connection. Each of the four tipi landings has a unique railing design including various geometric patterns.

Determining how to frame the tipis posed a challenge. HDR decided that this would be a good application for a reciprocal frame and modeled this in 3D to determine the size and placement in order to provide the proper clearance and headroom. HDR started the process by making a simple model from pencils in order to show the designers and drafters the concept, then refined this by making a 3D CAD model and sharing it as a 3D PDF that could be opened and rotated in space.

Spread footings were selected for all of the foundations. The underlying materials consisted of dense gravels to a depth of about 20 ft with clays and silts below this. The geotechnical

➤ A truly 3D model of the tipi structure.

Brad Miller

members of the design team expressed some concerns that the weight of the massive concrete abutments (faced with natural rock) that were used, in conjunction with the weight of the long bridge span, would cause long-term settlement. Similar concerns had arisen with other recent highway projects in the area. In order to minimize the dead load of the abutments and the potential for long-term settlement, HDR designed the abutments to be hollow or have Styrofoam blocks embedded in each column leg.

The project was completed in the spring of 2011. Thanks to its lightness and aesthetic considerations, including the use of weathering steel and steel-framed tipi structures, the bridge fits into its rich scenic and cultural surroundings in the beautiful Mission Valley, while providing safe passage over Highway 93 and connecting Salish Kootenai College with the rest of Pablo. MSC

Owner
Montana Department of Transportation

Client
Confederated Salish and Kootenai Tribes (CSKT)

Structural Engineer
HDR Engineering, Inc., Missoula, Mont.

Architectural Design
MacArthur Means and Wells Architects, Missoula

General Contractor
Quality Construction, Missoula

Since 1906, the Chicago and Alton Railroad Bridge has taken trains over the south branch of the Chicago River.

Serving the South Side

BY JIM TALBOT

STEEL CENTURIONS
SPANNING 100 YEARS

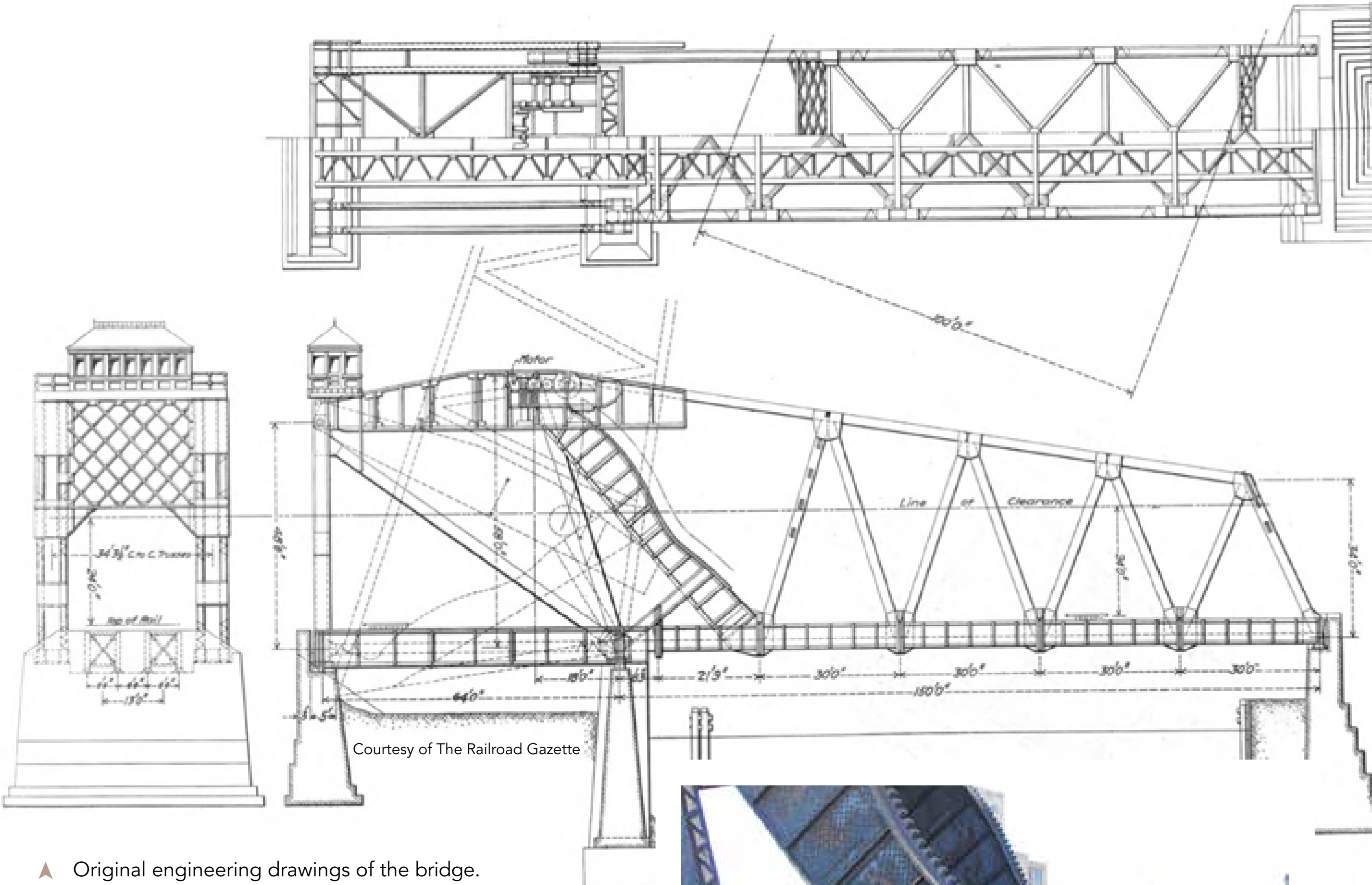
Our nation's rich past was built on immovable determination and innovation that found a highly visible expression in the construction of steel bridges. The Steel Centurions series offers a testament to notable accomplishments of prior generations and celebrates the durability and strength of steel by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

IN TERMS OF ITS MOVABLE BRIDGES, Chicago can be considered world-class. The city's first movable bridge was built in 1834, and many of its movable bridges set size and weight records when originally constructed. Today, more than 60 movable bridges of various types—trunnion bascule, Scherzer rolling lift, swing and vertical lift bridges—remain in and around Chicago, although about half no longer move.

This month's Centurion is one of those that no longer move: the Chicago and Alton Railroad Bridge, a designated Chicago Landmark built in 1906. This fixed-trunnion, single-leaf bascule (French for "seesaw and balance") rotates around a large axle. The trunnion bascule is sometimes called the Chicago bascule because the city's designers and engineers perfected this bridge type early in the 20th century, and several of them cross many of the city's waterways.

Reaching across the south branch of the Chicago River, the bridge is adjacent to Interstate 55 and a station on the city's "L" train system. Chicago consulting bridge engineer William M. Hughes designed the bridge (the contractor for the superstructure was the American Bridge Company and the erector was Kelly-Atkinson Construction Company). Its rarely implemented design, patented by John W. Page, stands as perhaps the only surviving bascule bridge of its type and the first bascule built for railroad use. Aside from the Chicago and Alton railroad, it also served the Illinois Central, the Atchison, Topeka and Santa Fe and Wisconsin Central railways.

The bridge replaced a bobtail swing bridge dating to the 1880s, which was kept open during construction, and construction took place with the new bridge in the raised position. The design provided clear headroom of 17 ft for rail traffic during construction, and during the switch between bridges difficulty in demolishing the swing bridge caused a rail traffic delay of 24 hours rather than the expected ten hours.



Courtesy of The Railroad Gazette

Nathan Holth

▲ Original engineering drawings of the bridge.

◄ The fixed-trunnion, single-leaf bascule bridge today.

► The gear rack for the bridge.

Vertical Free

Essentially, the Chicago and Alton Railroad Bridge is a steel, riveted, five-panel, Warren through truss with no verticals. The bridge has a span, from the trunnion, of 150 ft and a total length of 214 ft. It offers a clear channel of 100 ft for river navigation. The bridge's width of about 34 ft supports two sets of train tracks, and the 64-ft approach consists of a riveted steel plate-girder span. The superstructure design is such that each track can carry a moving load of two locomotives, each weighing 192.5 tons, and followed by 5,000 lbs./linear ft.

The approach—along with the motors, machinery, supporting girders and tender house—also serves as part of the bridge's counterweight. The remaining counterweight on the inside girders consists of concrete placed on buckle plates riveted to the machinery girders, and the counterweight on the outside girders consists of cut iron blocks bolted to the webs. The design is such that during operation, all moving parts are virtually in balance. The only power required is that which is necessary to begin movement and overcome wind and friction.

Two 70-ton rack guides with an unusual curved shape lie outside the truss. There were originally two 124-horsepower motors mounted on the top frame to drive the pinions that engaged the rack teeth to raise and lower the bridge. The operator in the tender could view electric lamps that indicated four bridge positions during movement. A similar indicating lamp showed the position of the end lock. Complete movement in either direction took about 90 seconds.

Phosphor bronze serves as the bearing material for the trunnions, roller shafts, rollers and the rear pins for the counterweight girders. All shaft bearings are Babbitt metal. Total cost of the superstructure, including the erection and electrical equipment, was about $116,000. MSC

*Jim would like to acknowledge **www.historicbridges.org** and its author/photographer/webmaster Nathan Holth (**nathan@historicbridges.org**). Holth is also the author of* Chicago's Bridges, *which includes photography and discussion of Chicago's many movable bridges, including the Chicago and Alton Railroad Bridge.*

Jim Talbot is a freelance technical writer living in Ambler, Pa.

There's always a solution in steel.

American Institute of Steel Construction
One East Wacker Drive, Suite 700
Chicago, IL 60601

312.670.2400 www.aisc.org

National Steel Bridge Alliance
A division of American Institute of Steel Construction
One East Wacker Drive, Suite 700
Chicago, IL 60601

312.670.2400 www.steelbridges.org

Item NSBA-005