National Steel Bridge Alliance

2007 PRIZE BRIDGE *Competition*

The NSBA Prize Bridge Competition honors significant and innovative steel bridges constructed in the United States. Awards are presented in a variety of categories, including long span, medium span, short span, movable span, major span, reconstructed, and special purpose.

The National Steel Bridge Alliance thanks the submitters of all of the outstanding entries for their participation in the 2007 Prize Bridge Competition. The projects were judged on:

- Innovation
- Aesthetics
- Design and engineering solutions

Designers of the winning Prize Bridge projects will receive award plaques during a dinner banquet at the 2007 World Steel Bridge Symposium in New Orleans, December 4–7, 2007. Owners of winning bridges will receive award plaques at a dinner banquet during the 2008 AASHTO Bridge Subcommittee meeting.

Jurors for this year's competition were:

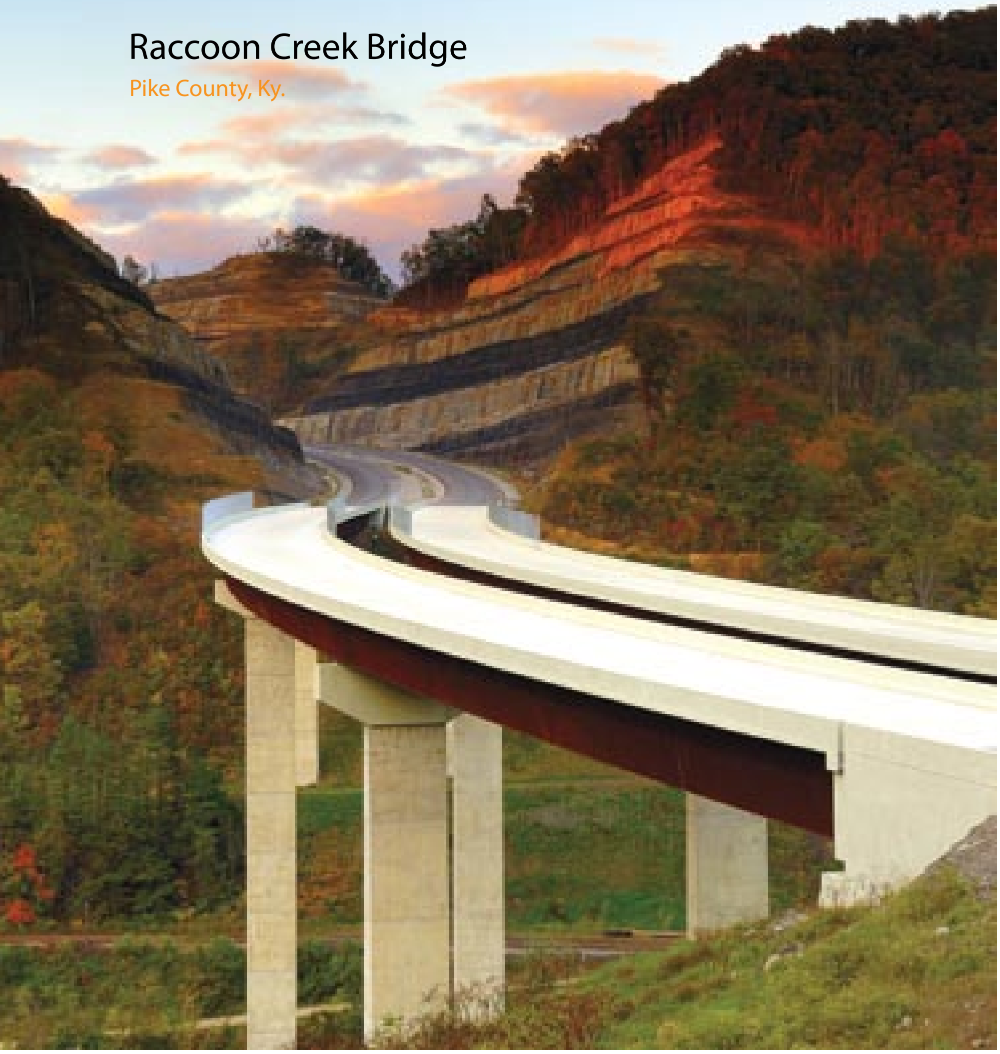
- Thomas Lulay
  CH2M Hill, Salem, Ore.
- Matthew Farrar, State Bridge Engineer
  Idaho Department of Transportation, Boise
- Myint Lwin, Director
  FHWA Office of Bridge Technology, Washington, D.C.
- Andrew Herrmann, Managing Partner
  Hardesty and Hanover, New York

NATIONAL AWARD

LONG SPAN

Raccoon Creek Bridge

Pike County, Ky.



Owner
Kentucky Transportation Cabinet, Pikeville, Ky.

Designer
Palmer Engineering, Winchester, Ky.

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

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

General Contractor
Bush & Burchett, Allen, Ky.

Raccoon Creek Bridge is part of U.S. Route 119 in Pike County, Ky. This section of relocated U.S. 119 is a four-lane divided highway through mountainous terrain and is one of the last sections of Corridor G of the Appalachian Development Highway System, a network established by the Appalachian Regional Commission to support economic and social development in the region.

The $20 million bridge consists of twin structures that begin in a 3,280-ft radius curve with a 4.8% superelevation, transition through a spiral, and end in a tangent section of roadway. The bridges are 1,275-ft-long four-span structures with maximum 380-ft spans crossing 212 ft above Raccoon Creek. Three piers ranging from 140 to 210 ft tall support each bridge.

Design

Long spans were required for this curved mountain road as the third span crosses Raccoon Creek Road, Raccoon Creek, two railroad tracks plus a spur track, and a coal mine's entrance and access roads. These same constraints that dictated long spans also restricted the contractor while building the bridge. Limited workspace, combined with the 200-ft height of the bridge and the weight of the box girder segments, truly created a one-of-a-kind construction job.

During preliminary design of the bridge, welded steel plate girders were sized for the long, curved spans. The design met the owner's load requirement (AASHTO HS25 design), but showed large differential deflections under truck loading—i.e., the deck rotated because the beams on the outside of the curve deflected 8 in. more than the beams on the inside. This inherent flexibility of the I-girder bridge type was an even greater concern because Kentucky has a legal load limit of 126,000 lb for trucks hauling coal.

In addition to in-depth evaluation of the bridge's in-service performance under traffic loading, constructability of the bridge was also investigated. Instability of the flexible I-girders during erection and installation of cross frames could have caused considerable problems. Even if construction were accomplished with the necessary, extraordinary measures, the traveling public would likely be able to sense deck rotation and not be at ease with this crossing.

The design team met with the owner to discuss these concerns. After a discussion of possible mitigation measures, all parties agreed that a different bridge type was needed to overcome the deck rotation problem and construction challenges. Although steel box girders had not been used before in the state, the design team decided on this girder type as it is much stiffer torsionally and is well suited for curved bridges.

Even once the decision was made to switch

the bridges to steel box girders, building within the constrained site remained a challenge. To address this matter, a partnering meeting between the owner, the consultant, and potential contractors was held to obtain suggestions aimed at preventing problems during construction. Contractors were shown design concepts and asked for comments on constructability concerns. Main comments were: 1) beam segment weight should be minimized to allow for smaller, more economical cranes; and 2) a possible construction sequence should be developed and included in the contract plans.

Including a detailed construction sequence in the plans is typically done for very large, complex, or segmentally constructed bridges where the method and sequence of construction can greatly affect stresses within the bridge. Recognizing the uniqueness of the Raccoon Creek Bridge situation, the owner agreed to include a suggested erection scheme in the contract plans. Presenting a sequence where construction stresses remained within allowable limits ensured a biddable project, although alternate schemes would be allowed if the contractor desired.

Construction

The erection sequence suggested in the design plans utilized temporary girder supports sometimes called "angel wings." These supports were fastened near the top of the tall piers and created stable platforms for the girders. Once a girder segment over a pier was secured in place, the temporary supports allowed for balanced cantilever construction. After completing the balanced cantilever portions from the piers, construction progressed with simultaneous drop-in girder sections, resulting in efficient erection.

Early Warning

By designing the Raccoon Creek Twin Bridges with their construction complexities in mind, engineers encountered and conquered obstacles in the preliminary phase, allowing the owner to avoid costly changes before or during construction. The project demonstrates a way to reduce differential deflections if the combination of span length and curvature create problems. A very difficult bridge construction project was improved by using more stable box girders in combination with temporary supports attached to the tall piers. MSC

NATIONAL AWARD

MAJOR SPAN

Burro Creek Canyon Bridge

U.S. Highway 93 between Phoenix and Las Vegas

Owner/Designer
Arizona Department of Transportation, Phoenix

Consultant
URS, Phoenix

Fabricator
PDM Bridge, Eau Claire, Wisc. (AISC Member)

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

Erector
Traylor Brothers, Irvine, Calif.

General Contractor
R.E. Monks, Fountain Hills, Ariz.

Arizona U.S. Highway 93 runs north to south through central Arizona and is the primary transportation corridor between Phoenix and Las Vegas. Transportation growth through this corridor and related safety concerns have necessitated an expansion of the corridor—and a second Burro Creek Bridge.

The existing Burro Creek Bridge, which carried two-way auto traffic, is a truss arch structure with spandrel columns supporting the roadway deck and plate girder approach spans. The final design for the new bridge design was also a truss arch, but using weathering steel for future maintenance reasons. The existing Burro Creek Bridge will be painted in the future to blend aesthetically with its new sister.

The location is environmentally sensitive, part of a wilderness recreation and campground area, and owned by U.S. Bureau of Land Management (BLM). This federal agency, as steward and custodian of the unique canyon area, had set a higher level of environmental restraints for this new bridge crossing over the canyon. Major constraints included: minimal damage and disturbance to the canyon, preservation of the natural settings and compatibility, no construction access to the canyon base, and maintaining a scenic view from the nearby campground. The Arizona Department of Transportation (ADOT) developed a partnering relationship with BLM early in the planning and design process, and BLM concerns and priorities were included in the layout and bridge type selection.

Learning from Lessons Past

The existing Burro Creek Bridge offered insight as to how to deal with the challenge of erecting a structure—that would not be internally stable until it was complete—over a significant opening. A cable high line was used with the first bridge to deliver material and erect the structural steel. A cable-stay tower was also used for temporary erection support, as the truss arch stretched out from the abutments and ultimately closed at center span. The spandrel columns and decking were then erected with the high line once the main arch truss was complete.

This erection method was suggested by ADOT in the original project bid documents for the new bridge. However, the erector concluded that this method was slow and not competitive. Experience within the estimating team was drawn upon and lessons learned from previous projects were brought to the table. One such bridge project, in Washington state, was erected "over the top" with a light crawler crane. A bogie cart system was used to ferry materials to the erection crane as it walked forward to erect the truss bridge until the cantilevered halves closed at center span. But the New Burro Creek Bridge design, by itself, was not capable of self-support, nor was it capable of supporting an erection crane.

Another previous bridge project, in Michigan, was also considered. This through-arch structure, which was also erected with a crane over the top, used a temporary support tower with cable stays to support the arch erection and crane loads until the arch was completed. This erection method appeared to be adaptable to the New Burro Creek Bridge, and the tower components used for this bridge still existed and were available. As such, this was the chosen method for the new Burro Creek Bridge.

Laying the Groundwork

Extensive geotechnical investigation and iterative bridge foundation studies were performed to optimize the location of the bridge. A computer-based visual simulation study presented the impact and compatibility of the various feasible bridge structure types on the scenic view of the canyon.

Three-dimensional simulation models were developed to make comparative evaluation of alternative bridge types over the canyon setting and to aid in selection of bridge structure type. Innovative connection designs were developed to improve fabrication and erection methods and enhance construction safety. High-strength weathering steel was used to protect the environment and blend with the natural setting and rock types of the canyon. Special types of wind bracing and anchoring details at skewbacks were developed to streamline steel erection. In addition, special provisions and dynamic control parameters were specified in design to control rock-blasting effects.

The Right Fit

A steel truss arch bridge layout was selected as the best fit for the canyon. Arch skewback foundation layout and excavation limits were refined in order to reduce rock excavation and rock fall in the canyon.

Constructability issues of the steel arch over the canyon, with minimal disturbance and in close proximity of the existing Burro Creek Canyon Bridge with heavy traffic, were major criteria in the design development process. Several innovative and optimized design features were included to achieve these goals. Skewback piers were designed to

provide support and anchorage for the cantilever launch of the steel arch over the canyon. Flexible connection details were provided for ease of fabrication, transport, and field erection.

Erection productivity and worker safety were addressed using an access platform system. The contract specifications originally called for the use of safety nets, but the access platform system prompted the elimination of this requirement and afforded a heightened level of worker safety. This in turn resulted in improved erection productivity. A bottom platform extended across the lower chord joints, from which the lower arch truss members could be erected and bolted. The platforms were moved forward with the erection in a trapeze fashion. Upper erection platforms were smaller and specific to a single joint, and also served to provide erection access and later, a secure means to complete the joint bolting process. MSC

NATIONAL AWARD

MEDIUM SPAN

Gateway Bridges

Taylor, Mich.

Owner
Michigan Department of Transportation, Lansing

Designer
Alfred Benesch & Company, Lansing

Fabricator
PDM Bridge, Eau Claire, Wis. (AISC Member)

Erector
Whaley Steel Corporation, Mio, Mich. (AISC Member)

General Contractor
C.A. Hull, Inc., Walled Lake, Mich.

Unequal arch lengths, pressurized ribs, hidden arch ties, and even Super Bowl-inspired football-shaped braces characterize a new set of bridges in suburban Detroit.

The Gateway Bridges are part of a $55 million project to improve Interstate 94 between Detroit's airport and downtown. They replace a previous four-span struture and carry westbound and southbound I-94 traffic over a redesigned single-point urban exchange. The structures are twin 246-ft single-span inclined through arches, with the interior and exterior arch ribs inclined 25° toward each other in order to maintain the desirable vertical clearance over the roadway. The ribs are braced together using five football-shaped braces.

The unique physical appearance of the bridge incorporates innovative functional aspects, and several progressive engineering concepts were developed to aid in maintenance and provide longevity for the structures. The following are notable unique characteristics:

➜ This is the first tied arch with its longitudinal ties buried under the road (modified tied arch). The modified tied arch solves the redundancy issue with tied arch bridges.

➜ The arch ribs are not the same length, satisfying the desire to match the existing horizontal alignment of I-94 east and west of the Telegraph Road interchange. The base of the interior arch ribs is located at the level of I-94, while the base of the exterior arch ribs is located at the level of Telegraph Road. This caused the length of the exterior and interior ribs to be different—296 ft and 257 ft, respectively.

➜ The rib sections of the two arches are varied to achieve the same stiffness in each arch. This is done to ensure that the arch deflections will be the same.

➜ In order to reduce the size of the arch ribs, the shape of the arch is optimized to produce axial stresses in the rib with a minimum moment from dead load. Most of the bending stress comes from live load acting over a part of the span.

➜ The arch ribs are 3-ft by 4-ft box sections. Due to the small size of the ribs, future inspection and maintenance of the inside portion of the box

will be difficult. Therefore, the arch ribs are pressurized with air to prevent any internal moisture in an effort to prevent corrosion.

➜ The framing of the bridge deck is a series of floor beams, stringers, and stiffening girders. The transverse floor beams support a 9-in.-thick concrete deck, which in turn is supported by hangers. The longitudinal stringers and stiffening girders reduce the deck deflection due to live load. The stiffening girders also distribute the live load between the adjacent hangers. This resulted in lighter hangers.

➜ The hanger assembly has two strands per assembly. In the event of losing one strand per assembly, each strand within the assembly is designed to carry the total load of the adjacent failed strand with an impact factor of two. To reduce the possibility of wake galloping for the hangers, one separator is used to connect the two strands together.

➜ The transverse beams are haunched I-beams with portions of the beam extending outside the deck. These extended portions are boxed, using two additional outer webs, and then pressurized with air. The boxed-sections improve aesthetics and increase the torsional resistance of the beams in case one strand within the hanger assembly is lost or replaced.

➜ In true arches, the longitudinal arch thrust is taken by the foundation supports, such as the piles. In a tied arch, the thrust is taken internally by the tie. In both cases, there is no redundancy in case of a failure of the thrust resistance. For this bridge, the longitudinal arch thrust is resisted by multiple foundation elements—battered piles, longitudinal reinforced foundation ties, and the transverse foundation ties.

Cost-effective Aspects

Cost was a major concern of MDOT, and was therefore considered with highest regard. Design decisions were guided by cost implications resulting in significant savings from the original estimate. Each of the following was significant to the realized cost savings:

Optimizing arch ribs. A perfect arch would carry only compression under applied dead load. In order to reach the shape of the arch that will result in a minimum bending stresses under dead loads, the shape of the ribs was optimized to closely approximate the equilibrium thrust line, which corresponds to the applied dead loads. A compound circular curve was chosen to approximate the equilibrium thrust line. Starting from a basic circular profile with constant radius, the bridge was analyzed under dead loads, then the equilibrium thrust line was determined, and a compound circular curve was fitted through the thrust lines. The structural model was then re-analyzed with the new shape of the ribs. This iterative process was carried, in which the resulting dead loads from the previous analysis were used to generate a new shape for the ribs. The final shape of the arch ribs was reached when the bending stresses were negligible. This process resulted in a lighter arch ribs and small arch rib deflections under dead load.

The arches were optimized, making the most efficient use of materials while achieving the desired aesthetic result. This effort saved $500,000 in material costs.

Bridge assembly technique. Design specification required per-assembly of the arch, which contributed to the efficiency of construction. The first bridge took one month to construct. Having learned from the first erection, the second bridge was erected in 10 days.

Sealing and pressurizing the arch ribs ensures that maintenance will be minimized and traffic flow optimized during routine inspection, making the bridges cost-effective over time.

Transverse Beams. The transverse beams are 100-ft 2¾-in.-long haunched I-beams with portions of the beam extending beyond the deck. These portions are boxed sections using two additional outer webs. The boxed sections of the beams increase the torsional resistance of the beams in case one strand within the hanger assembly is lost or being replaced. Cost savings were realized by incorporating the I-beams as opposed to using complete box girders. The stringers act compositely with the deck through ¾-in.-diameter shear studs. MSC

NATIONAL AWARD

MOVABLE SPAN

Louisa Bridge

Louisa, La.

Louisiana's longest steel girder double-leaf bascule bridge spans the Intracoastal Waterway in remote Louisa, St. Mary Parish, La. The main navigational span is a semi-high-level, two-steel-girder, double-leaf, fixed-trunnion bascule bridge. The longitudinal bridge, with a trunnion-to-trunnion distance of 275.6 ft and a width of 40 ft, is one of the longest spans of its type in the United States. In the closed position, it provides a minimum vertical clearance of 73 ft and a horizontal navigation clearance of 200 ft.

The superstructure design for both the bascule and adjacent approach spans uses two shallow-depth parabolic-shaped welded steel plate girders for each span. These girders were selected for their efficient use of steel, light weight, durability, cost-effectiveness and aesthetic characteristics.

The bascule girder tail end utilizes a unique short and compact style counterweight. Special innovative steel counterweights were efficiently positioned in this tail end in order to minimize the overall counterweight size for aesthetic purposes. In the fully closed position, the bascule tail end seamlessly disappears within the adjacent approach spans, resulting in a pleasing three-span haunched girder-shaped superstructure. In the fully open position, the tail end disappears within the open-type bascule pier.

The very long and narrow bascule leafs required the floor system to be as light as possible. The floor system design, using steel stringers and steel floor beams supporting a light-weight open steel grating for the roadway deck, was selected for its efficient use of steel.

Louisa Bridge's shallow-depth parabolic bascule girders vary in depth from 7.5 ft to 17.3 ft and are spaced at 27.6 ft. The two adjoining steel girder spans vary in depth from 8.3 ft to 16.4 ft and are spaced at 33.5 ft.

Each leaf of the bascule is driven using curved racks mounted on each girder. The 73-ft vertical clearance means that the bridge will open infrequently. Therefore, a very basic drive system is used in each leaf; a single enclosed gear drive is driven by two 25-horsepower two-speed alternating current motors.

MSC

Owner
Louisiana Department of Transportation, Baton Rouge, La.

Designer
HNTB Corporation, Baton Rouge

Fabricator/Detailer
Carolina Steel Corporation, Greensboro, N.C. (AISC Member)

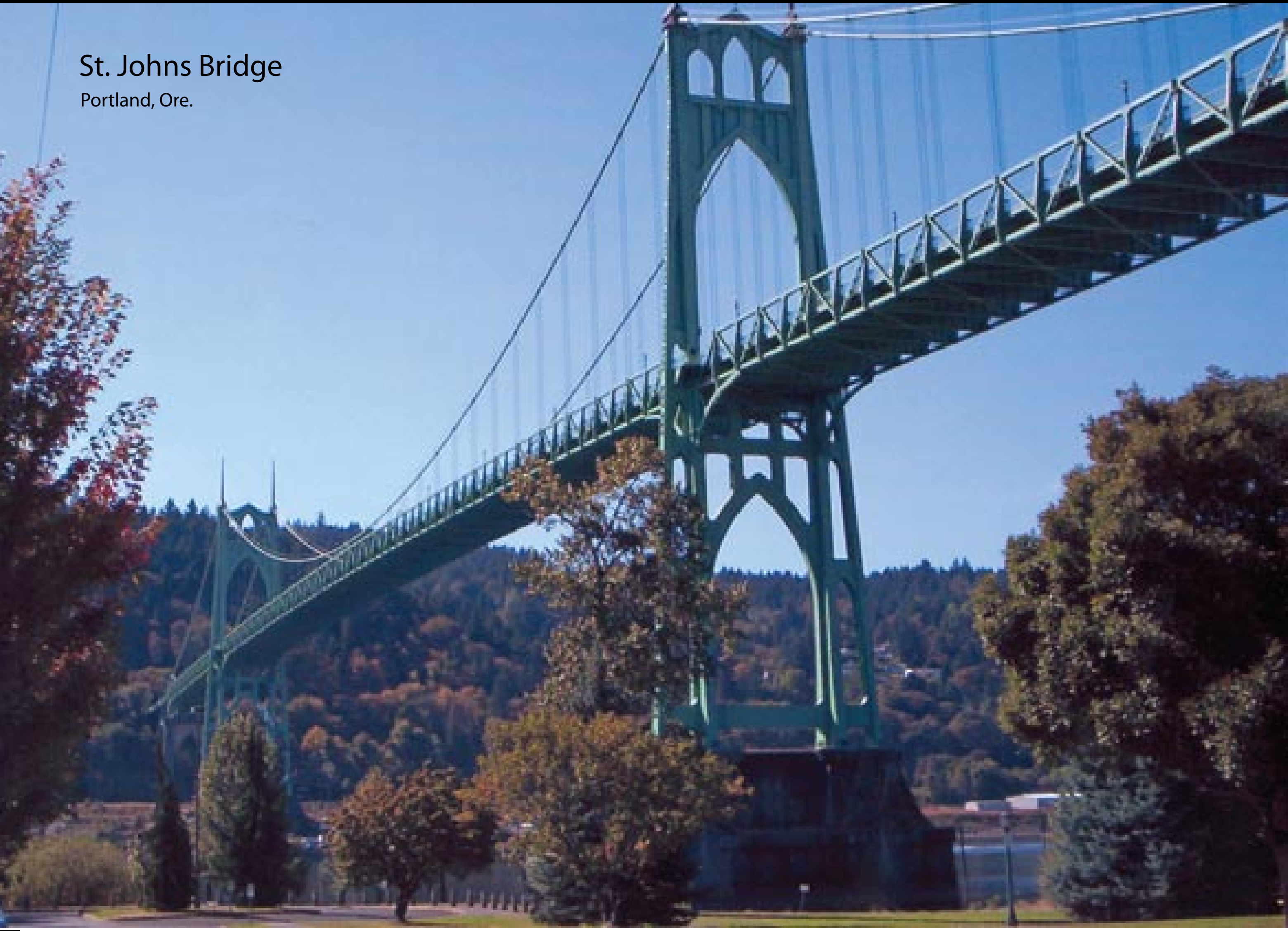
Fabricator/Detailer – Movable Span
Steward Machine Co., Inc., Birmingham, Ala. (AISC Member)

Erector
Huval & Associates, Inc., Lafayette, La. (AISC Member)

General Contractor
Coastal Bridge Co., LLC, Baton Rouge

NATIONAL AWARD

RECONSTRUCTED



St. Johns Bridge

Portland, Ore.

Owner
Oregon Department of Transportation, Salem

Designers
OBEC Consulting Engineers, Eugene, Ore.
Oregon Department of Transportation, Salem

Fabricator/Detailer
Hogan Fabrication, Inc., Portland, Ore. (AISC Member)

General Contractor
Max J. Kuney Construction, Spokane, Wash.

After more than 70 years of weathering the Pacific Northwest elements and a comprehensive inspection in the late 20th century, the historic St. Johns Bridge in Portland, Ore. recently underwent a $37 million restoration. Major work items on this 3,600-ft bridge included restoration of deteriorated steel, new deck, painting, main cable rehabilitation, suspender replacement, new railing, and seismic retrofitting.

St. Johns Bridge was designed by the famous bridge engineer David B. Steinman and was constructed in 1931 at a cost of $800,000. From west to east, the four-lane bridge consists of 255 ft of conventional steel deck truss approach spans; a 2,067-ft suspension bridge segment with suspended spans of 430 ft, 1,207 ft, and 430 ft; and 1,285 ft of conventional steel deck truss approach spans up to 180 ft in length. The bridge is the only large suspension bridge on the Oregon State Highway System and spans the Willamette River in Portland, providing more than 200 vertical ft of navigation clearance.

The Oregon Department of Transporation completed some of the design work in-house and used an outside engineering consultant for the remainder of the project. The rehabilitation included $16 million of painting, $11million for cable restoration work, a new $4 million concrete deck, and $5 million in miscellaneous rehab work including deteriorated steel restoration, bridge rail strengthening and rehabilitation, and seismic retrofitting. All work was staged to allow a continuous single-lane of traffic to be maintained in each direction at all times on the bridge.

Stiffening and other Factors

Stiffening was a major consideration for the renovation, and the design team performed extensive finite element and non-linear analysis on the bridge to determine areas of concern. The results indicated that the bridge was very close to excitation by wind and vulnerable to seismic events. The critical component was the slender stiffening trusses of the suspended main span, which have a span/depth ratio of L/67, well above most other suspension bridges of this size.

The typical deck section was modified by the addition of two tie braces between the deck and the floor beams, which allowed the concrete deck to become the fourth side of the "torsional box" deck section. This concept stiffened the bridge against wind excitation without changing the historic look of the structure, while using existing components of the bridge to the maximum extent.

Another method used to stiffen the bridge against wind excitation without changing the historic look of the bridge was the use of "traction rod" ties between the existing stiffening trusses and the main cables. The traction rods had an additional benefit of providing seismic restraint for longitudinal "slapping" of the superstructure into the seismically vulnerable towers supporting the main cables at deck level. The main cables were exposed and fitted for new traction rod clamps. The total weight of the new traction rod clamp castings was 38,000 lb, with the mid-span casting being the heaviest at 9,000 lb.

Justified Replacement

Out of 204 suspender cables, more than half were found to have enough broken wires to warrant replacement in kind with 1⅝-in.-diameter ASTM 603 wire ropes. The contractor provided the jacking scheme based on the designers' requirements and installed the ropes to the specified tension so as to maintain the distribution of forces in adjacent suspenders and prevent undesirable deflection in the structure.

The original main cables of the suspended span consisted of ninety-one 1½-in.-diameter bridge strands—each fabricated from individual wires—compacted into a hexagon shape with shaped Port Orford cedar used to form a circular shape, which was then wire-wrapped. Alternating rows of strands are fabricated with left-hand and right-hand lay to prevent rotation under loading. Sealing the main cable consisted of the use of a proprietary continuous Hypalon cable wrapping system. The wrapping is sealed at each cable band, splay cable, cable bent, and saddle and anchor house shroud. At low points in the main cable, inspection ports were installed with direct visual access to the bridge strands. These inspection ports can also be used for future cable corrosion control using the state-of-the-art dry air injection method.

The longitudinal steel stringers were originally constructed to be non-composite with the concrete deck. In order to replace the deck with a new concrete deck of similar thickness—combined with the need to strengthen the existing deck stringers to handle current vehicle loading—the new deck was made composite by the addition of shear studs to the top flanges. Approximately 7.5 miles of stringers were strengthened using approximately 60,000 shear studs. MSC

NATIONAL AWARD

SHORT SPAN

Box Elder Creek Bridge

Watkins, Colo.

Just a few miles east of Denver, an innovative six-span bridge crosses Box Elder Creek on U.S. Highway 36 in Watkins, Colo. The new bridge, which replaces a previous one, is 470 ft long and 44 ft wide, and carries two lanes of traffic. The project's total cost of $2.1 million includes removal of the old bridge, construction detour, and landscaping.

The superstructure is composed of 77-ft-long W33x152 rolled steel girders. The bridge has six girder lines of grade 50 weathering steel spaced at 7 ft 4 in. The bridge deck is 8-in.-thick cast-in-place concrete. The girders are simple span for non-composite dead load and were made continuous at the piers for composite dead load and live load.

A Competitive Alternative

Highway 36 highway makes a low crossing at Box Elder Creek, demanding a shallow superstructure. During the design stage the Colorado Department of Transportation considered precast prestressed concrete side-by-side box girders and structural steel girders; precast side-by-side box girders are the most common CDOT solution to the low-depth issue, due to the very competitive local precast industry. However, Colorado's standard precast concrete bulb-T shapes were too deep for the site, and steel was eventually chosen. The designers applied solutions generally reserved for precast concrete to this material alternative. These included:

- ➜ Simple-span girder sections made continuous at the piers for composite dead loads and lives loads.
- ➜ Simple, easily constructed details to obtain continuity at the piers.
- ➜ Using the deck to carry the tension component of the negative moment at the pier.
- ➜ Low-cost standard girder sections.
- ➜ Minimizing the number of diaphragms.
- ➜ Simple fabrication details.
- ➜ Simple construction details.

Although the Box Elder Bridge is not necessarily the first use of these innovative solutions for steel girders, by using them creatively and in concert the designers provided an alternative that was competitive with the normal precast concrete solution; project estimates showed the rolled W33×152 solution to be less costly than the precast concrete box girder solution. In addition, the W33×152 solution, as designed, was easy to build quickly.

To optimize the use of standard rolled steel sections, a simple yet unique compression plate detail was used at the piers. To carry the negative moment at the piers, the designers used a compression plate welded to the bottom flanges. This plate carried the compression component of the negative moment, and the composite bridge deck, with its rebar, carried the tension component.

Longitudinally adjacent girders sit on one 30-in. by 14-in. by 1-in. compression plate bolted to the pier cap and resting on an elastomeric leveling pad. One of the girders is shop-welded to the plate, and the other welded in the field. Consequently, the only field actions needed to obtain girder continuity were bolting the plate to the pier, field-welding one girder to the plate, and placing the bridge deck.

Rapidly Constructable Steel Details

To optimize the use of standard rolled steel sections, the "simple-span-made-continuous" technique (simple span for non-composite dead load and continuous for composite dead load and live load) was used to minimize both steel and fabrication costs. Making the girder continuous shared the live loads between spans, allowing a shallower girder section.

To save steel costs and construction time, intermediate diaphragms were not used between all the girders. Instead, they were placed in only three of the five girder bays between the six girder lines. All girder compression flanges were supported by a diaphragm, and all exterior girders were supported by a diaphragm—especially important during deck placement.

Single W27×84 rolled shapes were used for the diaphragms as opposed to multiple cross-bracing pieces. The diaphragms are spaced at 12 ft 8 in. in the two external bays and at about 19 ft in the internal bay. Similar diaphragms in all bays connect the girders at the piers and abutments.

Owner/Designer/Detailer
Colorado Department of Transportation, Denver

Fabricator
Big R Manufacturing, LLC, Greeley, Colo. (AISC Member)

General Contractor
Structures, Inc., Englewood, Colo.

The advantages of employing these details and using rolled beams were numerous:

➜ Fabrication costs were low, and therefore total steel costs were much lower than for welded plate girders.

➜ All pier cap compression plates and all diaphragm details were similar.

➜ After developing shop drawing for one rolled beam, all other drawings were the same or similar.

➜ With this bridge, continuity was obtained without any bolted girder splices.

➜ The girders were designed so that additional transverse stiffeners were not needed, other than those used for bearing stiffeners and to connect the diaphragms.

➜ Concrete diaphragms between the girders were not used at the piers or the abutments. This provided cost and construction time savings over the concrete diaphragms typically used for precast concrete girders.

➜ Using weathering steel eliminated the need for maintenance painting.

➜ Lifting the rolled beams was handled by relatively small cranes; the prime contractor was able to perform the steel erection.

➜ The total amount of structural steel needed for this bridge was only 20.7 lb per square foot of deck area!

Pier Details

The piers are founded on five steel pipe piles—which are ideally suited for the rather loose alluvial material making up the foundation soils—as opposed to the much longer pile lengths that would have been required for end-bearing piles or drilled shafts. The steel pipe piles were also less costly and quicker to construct.

The designers accomplished the most significant cost savings by using the pipe piles to create the five aesthetically pleasing round columns supporting the pier cap. The pipe piles were left extending out of the ground—with no pile caps or fussy transition details—and filled with concrete. Then, projecting reinforcing steel was inserted and the pier cap was constructed on top. Not only was this cost-effective, but it also removed several weeks from the construction schedule that would have been required had reinforced concrete columns been used.

Good Competition

The innovative six span steel bridge crossing Box Elder Creek in Colorado showcases the viability of standard rolled steel sections as a competitive alternative to precast concrete. The simple-span-made-continuous technique, although not new, was used with an innovative continuity detail and in concert with several other thoughtful design considerations, providing an especially economical, low-maintenance, and visually appealing bridge that was easy to fabricate and constuct. MSC

NATIONAL AWARD

SPECIAL PURPOSE

Highland Bridge

Denver

The new Highland Bridge restores a vital link between downtown Denver and the revitalized Highland neighborhood to the northwest. It replaces the 16th Street viaduct, a reinforced concrete viaduct that was failing when it was demolished in 1993, with a user-friendly pedway. It is the third in a family of three signature pedestrian bridges extending the city's downtown 16th Street Pedestrian Mall alignment across the Central Platte Valley.

Similar to the first two crossings, the Highland Bridge utilizes structural steel tubing and a cable-stay system for a dramatic structure. Rising 70 ft above the ground, the triple-rib steel arch spans 320 ft over Interstate 25. The flared cross-hanger arrangement provides a sweeping support system for the suspended bridge deck.

Design Vision

During the project's design, many structural steel options were evaluated, ranging from 200 ft to 350 ft long: single-rib arches, trussed arches, and bifurcated arches. Renderings were used during the design process by the architects, urban designers, and structural designers to share design concepts and solicit input from stakeholders and the public. Input from businesses, residents, and special interests, such as bicyclist groups, helped steer the project design. Critical to the urban design concept was the creation of a vertical circulation area to traverse a 13-ft change in grade from the structure deck down to the existing Platte Street elevation on the east side of I-25. The need for both long ramp access and stair access drove the design toward an architecturally sophisticated and urban solution. A circular ramp solution minimized impact on surrounding property while creating a plaza area with theater seating and direct access to nearby shops and a park.

The west end of the triple-rib arch anchors into a single-thrust block foundation. As pedestrians and bicyclists travel east across the bridge, the arch rib spacing increases, opening up and framing the downtown skyline, with each arch rib anchoring into a separate foundation.

Input from fabricators and contractors was solicited during the design to provide efficient and economic details. To facilitate construction over I-25, the arch fabrication was broken into four sections. Temporary splice plate connections between the arch pieces were designed for ease of erection and were removed once the arch steel pipe welds were completed.

Innovative Construction

To facilitate fabrication, the arch sections were fabricated upside down and fitted up to adjacent pieces for geometry control. The pieces were painted in the shop and shipped to the field, where each section was reassembled in a staging area north of the bridge site in preparation for erection. The arch sections were erected by crane during two consecutive night closures of I-25. The contractor's step-by-step sequence included a rolling procedure to orient the arch section upright and provide temporary falsework support for the end sections.

Design allowances during construction included sleeving the individual anchor bolts for each arch piece in the foundation, allowing up to one inch of adjustment in any direction. The sleeves and under-the-arch base plates were grouted after placement.

After the arch erection, the steel deck girders

Owner
City and County of Denver

Sturctural Engineer
Hartwig & Associates, Inc., Englewood, Colo.

Designer
Carter & Burgess, Denver

Fabricator
King Fabrication, Houston (AISC Member)

Construction and Erection Engineering
GES Tech Group - Consulting Engineers, Calhan, Colo. (AISC Member)

General Contractor
Hamon Constructors, Inc., Denver

were suspended with temporary cables prior to installation of the permanent 1.5-in.- to 1.75- in.-diameter cables. Because of the asymmetric layout and varying lengths and angles of the permanent cables, the deck girder geometry was set with a cambered twist, so that once the deck was poured it would match the proper geometry. The cable forces were monitored during the construction by measuring the cable vibration frequency. With the use of an accelerometer, the cable forces were calculated from the cable frequency, length, and weight. This method of measuring the cable forces was non-intrusive and can be used to conduct future routine inspections of the bridge. MSC